Metal Progress

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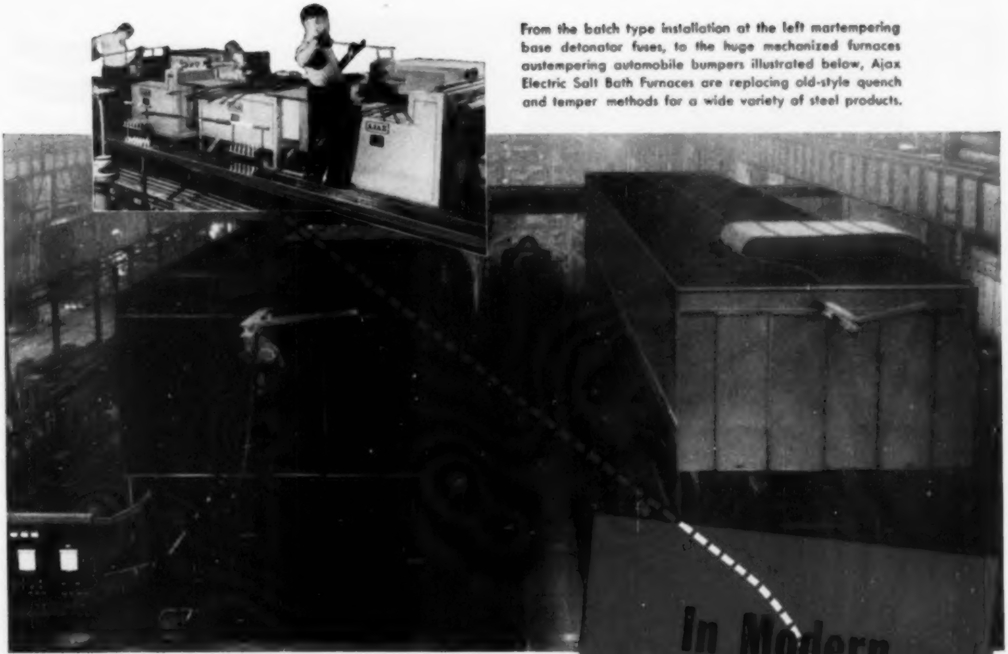
From the batch type installation at the left martempering base detonator fuses, to the huge mechanized furnaces austempering automobile bumpers illustrated below, Ajax Electric Salt Bath Furnaces are replacing old-style quench and temper methods for a wide variety of steel products.



In Modern Heat Treating— the Trend is to MARTEMPERING and AUSTEMPERING

From ring gears to plow points . . .

From bearing races to cast iron cylinder sleeves . . .

From uniformly shaped metal parts to odd and irregular sizes . . .

Scores of installations have proved the tremendous possibilities for economy, greater speed and efficiency in martempering and austempering, because all water and oil quenches are eliminated.

Distortion is so negligible that parts can be machine finished *before* hardening. Final grinding is eliminated or materially reduced. Scale, decarb and quench cracks are eliminated. Toughness and ductility are increased. The work is done materially faster—in less floor space—with lower labor costs. Let the Ajax Metallurgical Service Laboratory prove these claims on a specimen batch of your actual parts, under actual working conditions.

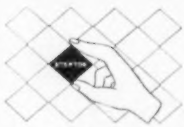
Write for Ajax Bulletin 120

AJAX ELECTRIC COMPANY, INC.
910 Frankford Avenue
Philadelphia 23, Penna.

World's largest manufacturer of electric heat treating furnaces exclusively

AJAX ELECTRIC SALT BATH FURNACES

Why Not Gear Up For Today's Production *This Way?*



For 11 years this Stentor blanking die and punch gave trouble-free performance, averaging 100,000 gears per grind. This record enabled management and production to avoid production delays by keeping machines operating with fewer shutdowns for resharpening. The precision gears, 120 teeth/90 pitch, are made from 24 ga., ¼-hard brass. In heat treatment the die moved only .0005″ on the maximum diameter of the gear.

It wasn't a happy coincidence that the tool and die steel was perfectly suited to put production from the tools on a smooth, trouble-free basis. It was planned that way—with the help of the Carpenter Matched Set Method. For the Method not only enabled this plant to eliminate costly experimentation in selecting the right steel, but enabled management to forecast output in advance because they could count on the tools to produce the parts *on time*.

Used in hundreds of plants, the Method offers far more than simplified tool steel selection. It makes machine operators more productive. It enables your plant to carry lower tool steel inventories. It makes heat treating easier, simplifies toolroom and production procedures. What's more, it is amazingly easy to apply. No extra cost or bother. To discover what it can do for you, ask for the new booklet "How to Get Better Tool and Die Performance". THE CARPENTER STEEL CO., 133 W. Bern St., Reading, Pa.

Export Department: The Carpenter Steel Company, Reading, Pa. "CARSTEELCO".

Carpenter

MATCHED TOOL & DIE STEELS

More than top-grade steels . . . a Method to keep tooling and production on schedule!

For your convenience, Carpenter carries warehouse stocks in principal cities throughout the country.

Polystyrene going in ...metal coming out

IN HIGH VACUUM a film of aluminum .000005" thick is about to be deposited on a load of transparent polystyrene plaques.

After they emerge from this 48-inch DPi Vacuum Coater at the Plastics Division of General American Transportation Corporation, the backs will get an over-all protective lacquering, and through the front expensive-looking, silvery letters will spell out the name of a famous make of refrigerator—ready to withstand thousands of scuffs by busy housewives.

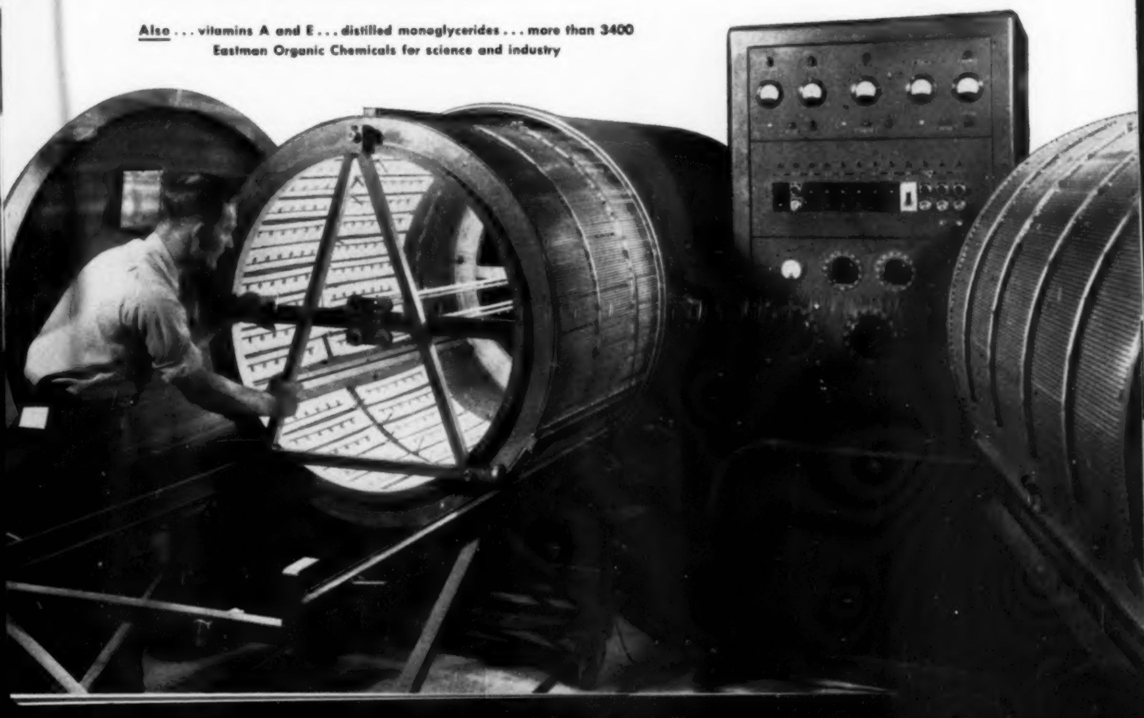
In the booming art of vacuum metallizing, this is called "second surface work." Low in cost as it is, there is an even less expensive technique of "first surface work." This means simply that the metal film, with its preparatory undercoat and protective overcoat, goes on the *outer* surface of molded items. The color and clarity of the base material may be whatever today's tight markets will provide, since a beautiful metallic coat will cover it.

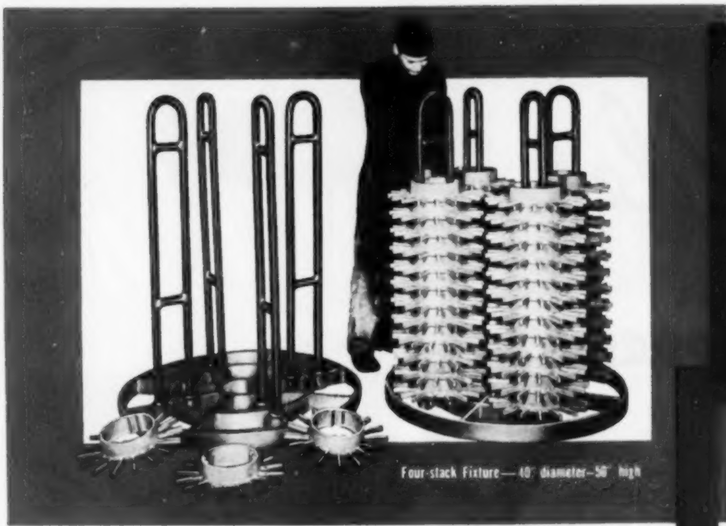
DPi makes the most efficient vacuum metallization equipment you can buy and stands ready to work with you in selecting your lacquers and lacquering equipment. We suggest you write for further information to ***Distillation Products Industries,*** Vacuum Equipment Department, 753 Ridge Road West, Rochester 3, N. Y. (Division of Eastman Kodak Company).

DPi

high vacuum research and engineering

Also . . . vitamins A and E . . . distilled monoglycerides . . . more than 3400 Eastman Organic Chemicals for science and industry





Four-stack Fixture—40" diameter—56" high

Center-post Fixture—22" diameter—28" high

Two-level Fixture—24" diameter—55" high

Furnace Loads Increased with D-H Fixtures "tailored for The Job"

When vertical carburizing furnaces became popular, Driver-Harris made close studies relative to loading capacities, and decided that fixtures specially designed to meet individual requirements would enable live load percentages to be increased, and loads to be more easily handled.

Custom-built equipment pioneered by Driver-Harris proved so successful that for fifteen years this firm has continued to specialize in producing furnace parts and fixtures "tailored for the job." In every instance, load ratio has been improved and load handling facilitated.

Here are a few typical examples picked from hundreds of applications in service today. These fixtures are made of Chromax* and Nichrome*—the high heat and corrosion-resistant alloys that are unsurpassed for heat-treating applications. Components consist of castings, forgings, hot rolled rod, sheet and wire—all produced in Driver-Harris' own plant to meet given requirements.

Such products exemplify the exceptional facilities at the disposal of Driver-Harris for designing and manufacturing equipment of this type. Moreover, since Driver-Harris is both producer and processor of numerous alloys, it is not prejudiced in favor of a particular material or process. Whatever is best suited to achieve peak performance is utilized. To have furnace parts and fixtures designed and produced by Driver-Harris, therefore, means that your specific needs are met in the most efficient manner possible.

Under present conditions, exceptional demand is engaging the resources of the Driver-Harris Company to an unprecedented extent. Nevertheless, we shall be happy to have you consult with us, and shall be glad to serve you to the best of our ability.

Nichrome and Chromax are manufactured only by

Driver-Harris Company

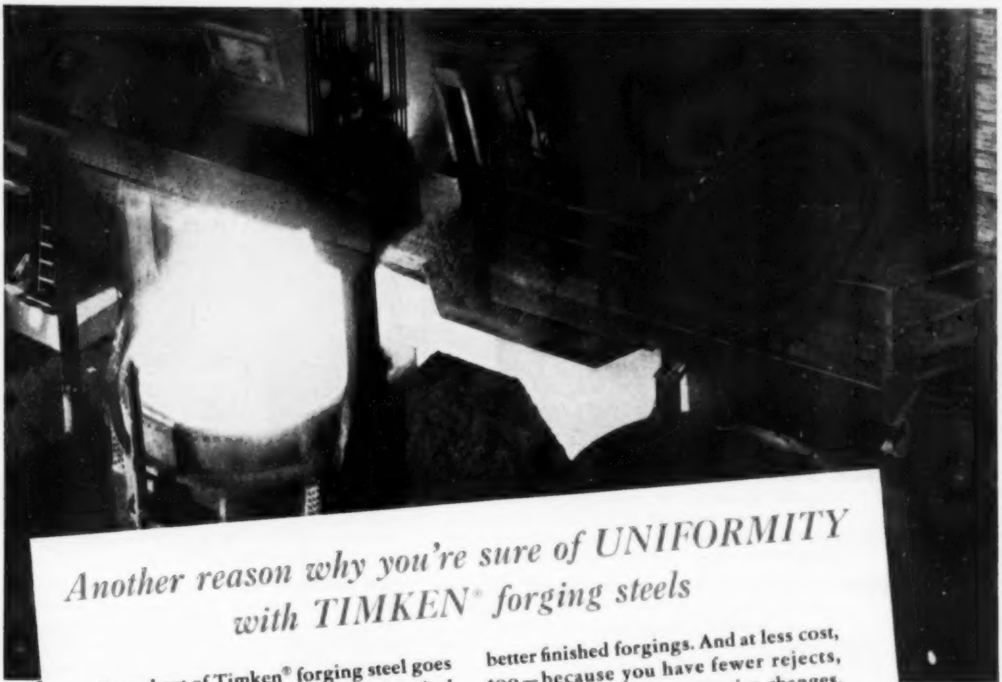
HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco

*T.M. Reg. U. S. Pat. Off.

From Bumper to Tailgate . . .
Reduces Deadweight and Increases Durability
N-A-X
HIGH-TENSILE STEEL
The widespread use of N-A-X HIGH-TENSILE steel in transportation equipment emphasizes two vital characteristics of this high-strength low-alloy steel.
1. Strength with less deadweight. N-A-X HIGH-TENSILE steel reduces deadweight . . . of great importance in transportation equipment and military vehicles.
2. Exceptional durability. N-A-X HIGH-TENSILE steel, with its high strength and toughness, has proved greater resistance to fatigue and impact at normal and sub-zero temperatures. Its inherent structure and composition greatly reduce the effects of abrasion and corrosion.
The response of N-A-X HIGH-TENSILE steel to severe cold-forming operations and its excellent weldability by electric arc or resistance, atomic hydrogen or heliarc, and all other processes, are added important characteristics of N-A-X HIGH-TENSILE steel.
SCRAP
STEEL
The "Eager Beaver"
The use of low-alloy, high-strength steels in military equipment assures longer life with less deadweight.
GREAT LAKES STEEL CORPORATION
N-A-X Alloy Division • Ecorse, Detroit 29, Michigan
NATIONAL STEEL CORPORATION

It's just been through 70 chemical check-ups



Another reason why you're sure of UNIFORMITY with TIMKEN® forging steels

Every heat of Timken® forging steel goes through 70 separate checks for chemical composition before tapping. And that's just one of many quality controls that assure you of uniform physical and chemical properties, uniform forge-ability, uniform response to heat treat-ment—from heat to heat and bar to bar.

This uniformity, plus superior surface and internal quality, helps you produce better finished forgings. And at less cost, too—because you have fewer rejects, fewer delays and shop practice changes.

For help with your forging problems, consult our Technical Staff. And for our bulletin No. 31, "Chemical Composition of Alloy Steels", write on your letterhead to The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

Specialists in alloy steel—including hot rolled and cold finished alloy steel bars—a complete range of stainless, graphitic and standard tool analyses—and alloy and stainless seamless steel tubing.

For *FAST* Foundry Floors use Lumnite* Heat-Resistant Concrete

At Silverstein & Pinsof, Inc., Chicago, workers were surprised when they returned after a one-day shutdown and found this Lumnite Heat-Resistant Concrete floor in place, ready for service.

TALK ABOUT SPEED! This tough Heat-Resistant Concrete floor was poured during a *one-day* shutdown. In service the very next day, it has taken the soaking heat of melting furnaces and the pounding of scrap boxes for 3½ years—and it's still going strong.

A RECORD? Far from it. You can *expect* speed with any Lumnite Concrete. It reaches service strength in 24 hours or less . . . cuts outage time on both Heat-Resistant and Refractory jobs. You can count on durability, because Lumnite Concrete withstands severe thermal shock. With suitable aggregates, it takes heat to 2600° F. And it's easily and economically poured in the shape and size needed.

Why not check now to see where you can speed construction and cut costs with Lumnite calcium-aluminate cement? It can be used for Heat-Resistant, Refractory or Insulating Concrete, depending on the aggregate. Lumnite has an enviable record of service and economy on such tough jobs as furnace car tops, door linings, arches and base pads, stack linings, and slow-cooling pits.

FOR CONVENIENCE, you may prefer to buy prepared Castable mixes. These packaged mixtures of Lumnite and selected aggregates are tailor-made to meet your specific temperature and *insulation* requirements. Add only water. They are made by refractory manufacturers and sold through their dealers.

For more information write: Lumnite Division, Universal Atlas Cement Company (United States Steel Corporation Subsidiary), 100 Park Avenue, New York 17, N. Y.

Constant pounding force of red-hot skulls being dumped hasn't hurt this Lumnite Concrete floor at Silverstein & Pinsof. Reports say floor is in good condition after 2½ years.

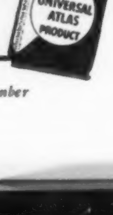
Lumnite Heat-Resistant Concrete worked so well for furnace room and slag dump floors that Silverstein & Pinsof is using Refractory Concrete to reline doors of melting furnaces.

"LUMNITE" is the registered trade mark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.

MP-L-51

ATLAS® LUMNITE for INDUSTRIAL CONCRETES

REFRACTORY, INSULATING, OVERNIGHT, CORROSION-RESISTANT



NBC SYMPHONY SUMMER CONCERTS—*Sponsored by U. S. Steel Subsidiaries—Sunday Evenings—June to September*


more than ever-
quality counts
in the home!
more than ever- Superior
STAINLESS STRIP STEEL
gets the call!
Stainless is chosen by discriminating homemakers for beauty and permanence . . . SUPERIOR Stainless Strip Steel is specified by experienced fabricators for its many production advantages.
• Let us detail them for you!
Superior Steel
CORPORATION
CARNEGIE, PENNSYLVANIA

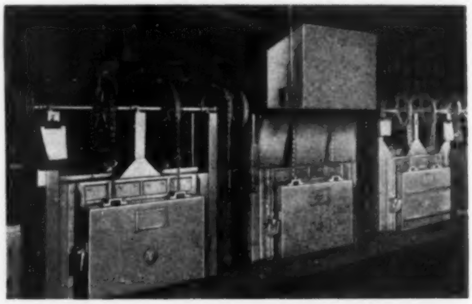
Super Refractories are used in almost all heat-treating furnaces

C. I. HAYES electrically heated, atmosphere controlled furnace used for forging stainless steel jet engine blades. This operation involves high temperatures and a high rate of production. CARBOFRAX silicon carbide material is used in the roof, floor and the front opening slot to give required abrasion and temperature resistance.

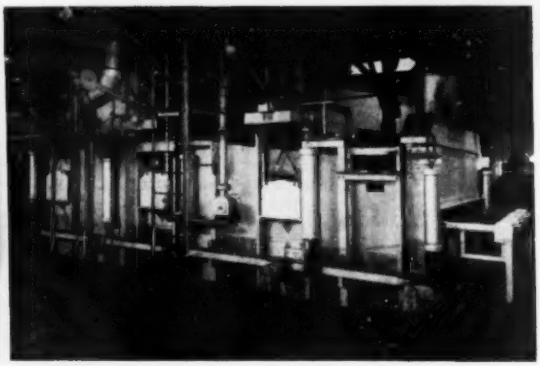
There's hardly a heat-treating furnace that, somewhere in the furnace, doesn't use Super Refractories by CARBORUNDUM — or couldn't do so profitably.

By selecting from their wide variety of base materials and bonds, CARBORUNDUM manufactures "job-designed" refractories to meet many exacting furnace conditions. Whether the problem is load strength, abrasion resistance, cracking resistance, or thermal conductivity, chances are that one of these Super Refractories, or a combination of them, can give the operating characteristics that you are looking for. Their use improves furnace efficiencies and helps deliver a better quality product.

We have a free booklet that outlines specific applications of these Super Refractories. May we send you a copy?



STANDARD FUEL ENGINEERING COMPANY furnaces used for hardening and pack carburizing. CARBOFRAX hearths stand up under the heavy loads and abrasive conditions encountered — also provide high thermal conductivity. The burner tunnels, made of ALFRAX aluminum oxide cement, are long lasting and retain proper size openings.



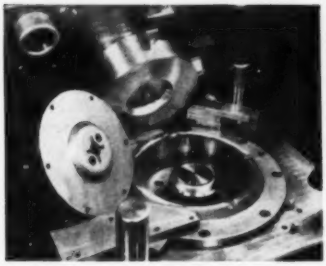
PENNSYLVANIA INDUSTRIAL ENGINEERS (Div. of Amsler Morton Corp.) walking beam furnace. The work rests on CARBOFRAX rails which provide necessary resistance to impact, abrasion and high temperatures.

THE CARBORUNDUM COMPANY

Dept. C-81, Refractories Div. **Perth Amboy, New Jersey**

Tool Steel Topics

BETHLEHEM STEEL



A-H5 tool steel is the backbone of this die which forms the flywheel element of a Borg-Warner automatic transmission from .1495-in. steel sheet in a 750-ton press. This die must hold accurate size during hardening because it produces precision parts.

Precision dies of A-H5 for Borg-Warner transmissions

Talk to the production men at McIntosh Stamping Co., in Detroit. Ask them how they like the A-H5 tool steel they're using in many of their precision dies. They'll tell you it's doing a good job. It's highly resistant to distortion during heat-treatment. It wears well on long runs, has durable cutting edges, and takes a lot of shock in heavy-duty stamping presses.

A-H5 is our 5 pct chromium air-hardening grade that comes close to the high-carbon, high-chromium grades in its safe, accurate hardening properties. Yet it's as economical as most oil-hardening grades. Easy to machine and heat-treat, too. It's being used more all the time by tool and die makers who want a general-purpose grade, one that's a consistently fine performer and needs no pampering.

A-H5 tool steel adds wear and shock-resistance to this high-production die, hardened to Rockwell C-58, which forms the back-plate for a direct-drive clutch from .2092-in. steel sheet in a 250-ton press.

Photos courtesy of McIntosh Stamping Co., Detroit. Parts used in automatic transmission made by Long Mfg. Co., a division of Borg-Warner Corp.

Customer in Jam, Distributor Flies Tool Steel to Him in Own Plane

The phone rang the other day at the home of one of our distributors while he was at breakfast. It was one of his New England customers in a city several hours distant by car.

"I'm in real trouble," moaned the customer. "I need some tool steel in the worst way. And I've got to have somebody to show us how to heat-treat it. Every hour is costing me plenty!"

Our distributor jotted down the details and grabbed his hat. He rushed over to his warehouse, had the short bars cut to exact length, and loaded them in his car. Then he headed for the airport. Here was his chance to cash in on his week-end flying lessons!

At the airport they had a red monoplane ready, engine warmed up and rarin' to go. In a matter of minutes he was taxiing down the field and off he roared into the wild blue yonder. And in less than two hours after the phone call he was delivering the tool steel and giving the grateful customer some pointers on how to heat-treat it for best results.

Not every Bethlehem distributor can personally fly tool steel to you to meet an emergency. But when you need fast delivery, your Bethlehem distributor is ready to rush your order for popular grades and sizes of carbon tool steel, oil- and air-hardening grades, shock-resisting, hot-work, and high-speed steels. He carries tool bits, brake die steel and other specialties that you need frequently. And he knows that he can call on the Bethlehem tool steel metallurgists to solve unusual problems and to handle special orders with our mill and laboratories.

They're mighty capable folks to depend on for tool steel service, whether it's an emergency, a tough problem, or a routine requirement. That's why we say: "Hats off to the Bethlehem Distributors! They're doing a real job!"

Most toolmakers know that decarburized metal must be removed completely from the working surfaces of tools. But it is not so widely known that it's often best to remove this skin from other portions of the tool.

This precaution is especially necessary on tools subject to repeated impacts. For example, a pneumatic chisel having a forged shank often breaks because of a fatigue failure. Usually there is a stress concentration in the shank, due to the change in section; and when this tool surface is also decarburized, rapid failure in service can occur.

The outer layers of a decarburized tool just don't have the strength of the effectively hardened tool steel base. The only safe thing to do is grind off the "decarb" on *all* tool surfaces.

Bethlehem ULTRASONIC TESTED **Tool Steel**

DEPENDABLE...

- Generous Sized Cabinets
- Conditioned Cooling System
- Built-In Checklite System
- Oversized Components
- Filament Voltage Regulation
- Industrial Type Tubes

OR ELSE...

Lindberg's built-in bloodhound—the exclusive "checklite" system—adds the 'or else' quality to dependable operation. "Checklites" are a system of indicating lamps that instantly track down any abnormal operating condition at any of the many protective devices.

Yes . . . dependable . . . rugged . . . and versatile! Lindberg Induction Heating Units are designed and built to operate under rigid production requirements far beyond the usual capabilities of Induction Heating Equipment. Like the bloodhound who never quits the trail, these units will serve you 24 hours a day . . . day after day . . . month after month.

Plants throughout the nation report dependable, versatile operation—fast, accurate, selective heating—on tiny pins—on mammoth gears —controlled in both depth of penetration and area covered. Investigate the Lindberg Induction Heating Units—you will profit from their rugged ability to deliver 24 hour a day operation. Ask for Bulletin 1440.

LINDBERG HIGH FREQUENCY DIVISION

Lindberg Engineering Company, 2448 W. Hubbard Street, Chicago 12, Illinois

Steel saved civilization at Vienna

MODERN history begins with the record of conflict between Christians and Moslems--six centuries of wars that opened with the Crusades and saw the Turks capture Constantinople in 1453.

More than 100,000 Turkish janizaries and cavalry besieged Vienna in 1683. For two months, to quote the diary of an eye witness, "The enemy continued playing their cannon and granadoes. But the city walls were strong, Christian cannon were bigger and more numerous and ammunition more plentiful." Finally came a day when the officer's journal reported, "The enemy did not play their cannon so fast. It was confirmed that they had no great provision of bullets, inasmuch as they shot back not only our bullets, but also pummels of swords and all sorts of iron and stones."

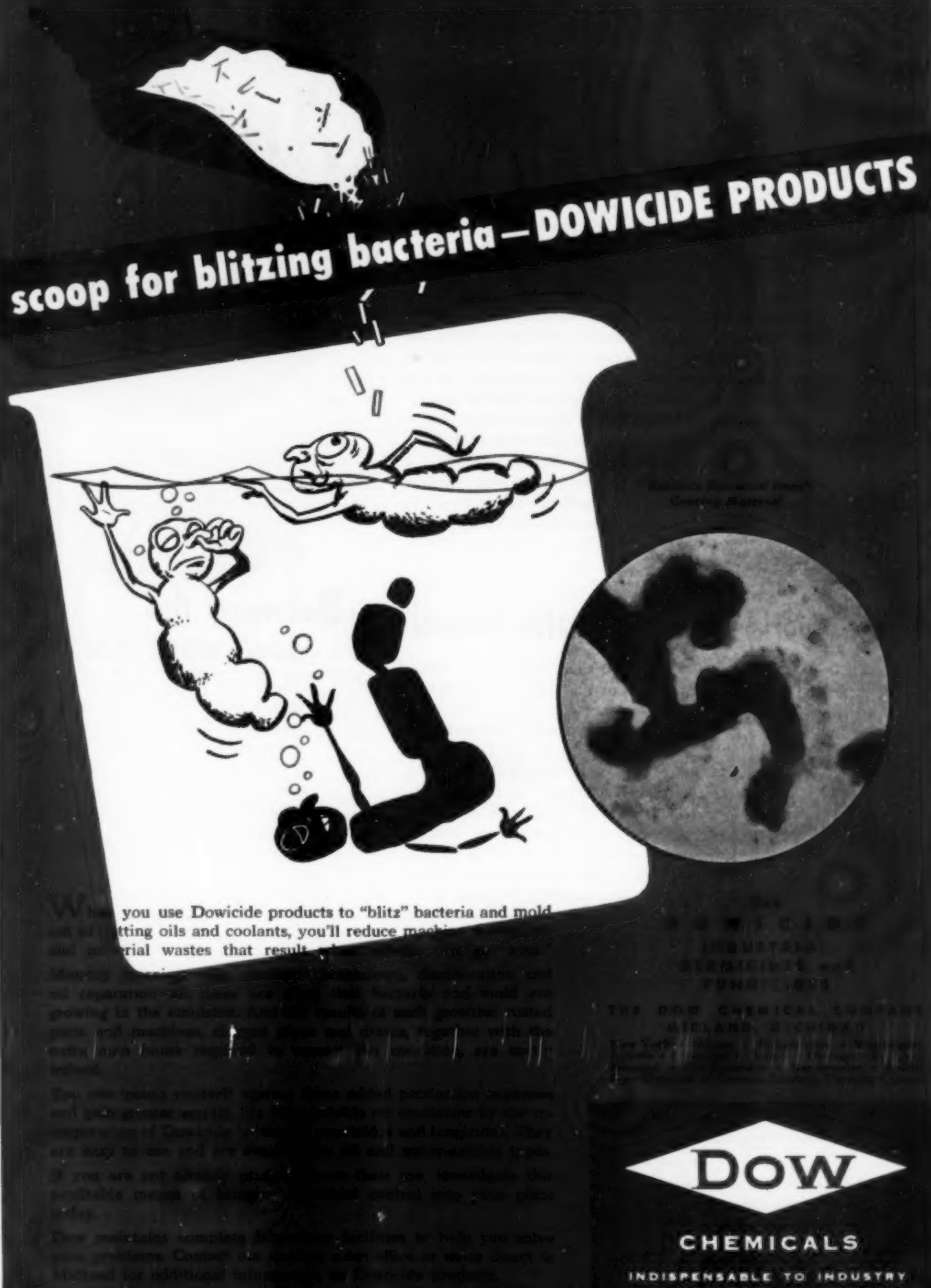
At last a great Christian relief army was assembled. "They made an attack in the best order that ever army did. The enemy, forced always to give back, were put all into confusion. They betook themselves to flight, leaving all their provisions, ammunition, cannons and tents --the greatest part rendered unfit for farther use by our great guns."

Never again did the Turks seriously menace Christendom. Western civilization had been saved once more by its supremacy in the use of iron and steel. To aid our survival America's free private industry is producing steel at the highest rate ever known--and still expanding. The question remains--Will America use enough of this tremendous steel production to guarantee the continued supremacy of Western, Christian civilization?---We believe the answer is yes!

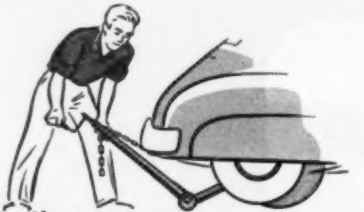
YOUR SCRAP IS NEEDED
YOUNGSTOWN

The Youngstown Sheet and Tube Company
General Offices--Youngstown 1, Ohio
Export Offices--500 Fifth Avenue, New York
MANUFACTURERS OF CARBON ALLOY AND YOLOY STEELS

The steel industry is using all its resources to produce more steel, but it needs your help and needs it now. Turn in your scrap, through your regular sources, at the earliest possible moment.



scoop for blitzing bacteria—DOWICIDE PRODUCTS
you use Dowicide products to "blitz" bacteria and mold
tting oils and coolants, you'll reduce
rial wastes that result
Dow
CHEMICALS
INDISPENSABLE TO INDUSTRY AND AGRICULTURE



Jack of all cars

Ever have trouble changing a flat on that low-slung car of yours? Well, here's a jack that eliminates the headache. Made by the Triangle Jack Co., Inc., of Wichita, Kansas, it can be instantly adjusted to suit the road clearance of any car. An Everdur Copper-Silicon Alloy is used for an important part of the screw mechanism because the manufacturer found it stronger, tougher and generally superior to all other non-ferrous metals tried.

No chance for replacement here

Expansion and contraction are important problems in bridge and highway construction. A bearing surface capable of supporting the tremendous, shifting weight of the superstructure must be provided. Bridge plates of Anaconda Rolled Phosphor Bronze, one of the best bearing metals known, have been installed in many of the country's largest structures, including the Macombs Dam Bridge approach of the Major Deegan Expressway, New York City. Fabricated with graphite-lubricated inserts in trepanned grooves by Merriman Brothers, Inc., Boston, and used in conjunction with a rocker assembly, these Anaconda Bridge Plates will withstand lateral movement in any direction from now on.

We do this in self-defense

For many years our French Small Tube Branch has manufactured small diameter, thin-gage tubes of the highest accuracy commercially obtainable. One of the reasons for this is the constant use of the bore telescope on redraw stock . . . for a *small* defect in a large tube would mean a *large* defect in a small tube. Since a tube with an imperfect bore could not escape our final tests and inspection, it would be rejected and scrapped . . . hence, we have a mighty good reason for ferreting out any possible imperfections right at the start.

YOURS—FOR THE FIRST TIME! 25 years of corrosion-resistance data ...in 24 pages

This brand new booklet is the first of its kind in the brass industry. It explains the chemical and physical nature of corrosive attack in its various forms. Included is a tabulation indicating the relative corrosion resistance of the principal types of copper and copper base alloys when in contact with 183 different corroding agents frequently encountered. A penny post card will bring your copy of Publication B-36. Address: The American Brass Company, Waterbury 20, Conn.

What's so fascinating about a fire hydrant?

It all depends on the point of view. To the city engineer it's a comforting thought to know the manufacturer used the right metal in the right place. The stem, for instance, is one of the most vulnerable parts of a hydrant. It is subject to unusual stresses, strain and corrosive attack—and it has to be there when you need it! Leading hydrant manufacturers are using Everdur Copper-Silicon Alloys in increasing quantities for stems, stem-nuts, seat rings, drip valve holders, washers, bolts, barrels and other parts where a strong, tough, corrosion-resistant metal is required.

ANACONDA

the name to remember in

COPPER·BRASS·BRONZE

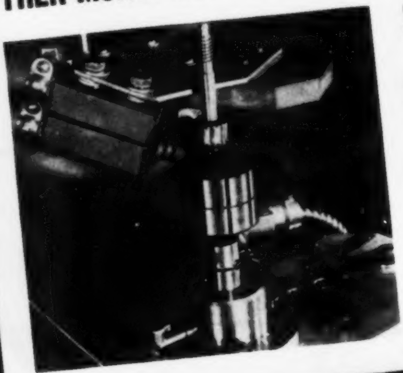
51102

THER-MONIC

THER-MONIC
INDUCTION HEATING CORP.
NEW YORK

NEW DEVELOPMENTS IN ELECTRONIC HEATING!

THER-MONIC BUILT UNIT USED IN CONJUNCTION WITH MODEL 285 (5 K.W.) THER-MONIC GENERATOR

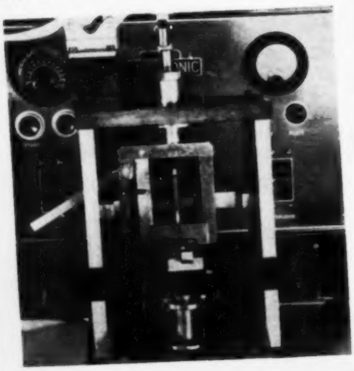


Solders SIX Armatures —in ONE Minute!

Armature is placed into an adjustable rotating spindle . . . and automatically brought into proper soldering position by push-button control. The operator touches wire solder to each terminal of the rotating armature to complete the operation.

WRITE FOR DETAILS!

THER-MONIC TABLE MODEL 50 (1 K.W. OUTPUT) PERFORMS FAST BRAZING OPERATION



Carbide-Tips ONE Micrometer Spindle —every FOUR Seconds!

Spindle, with piece of brazing alloy and carbide preplaced thereon, is inserted in heating position. Brazing temperature (1150°) reached in 4 seconds. Cooling blocks eliminate annealing of adjacent areas. Same THER-MONIC fixture also brazes carbide tips on micrometer anvil and other size spindles.

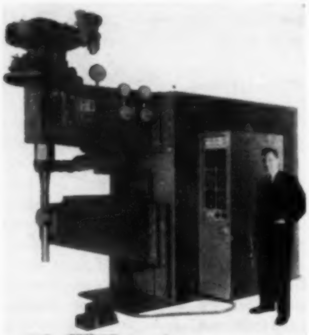
WRITE FOR DETAILS!

INDUCTION HEATING CORPORATION
181 WYTHE AVE., BROOKLYN 11, N.Y.

Engineering Digest

OF NEW PRODUCTS

LARGE SPOT WELDER: The "most powerful spot welder ever built" has been announced by Sciaky Bros., Inc. With an electrode force adjustable up to 23,000 lb. and a rating of only 400 kva, this machine is capable of ex-

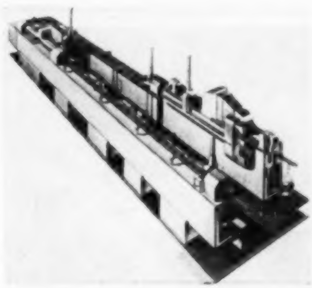


ceeding the requirements of the Air Force–Navy Aeronautical Specifications AN-W-30 (MIL-6860) and AN-W-32 (MIL-6858). Up to two thicknesses of ¼-in. aluminum alloy can be spot welded on a production basis.
For further information circle No. 134 on literature request card on p. 32B

BUFFING WHEEL: The new Airflow "pressure-cooled" buffing wheel, made by the United Buff Products Corp., is being used in the lamp, automotive, silver, stainless steel and copper industries. Ready for use as supplied, it requires no breaking-in, no inserts, spacers or dividers. Because of the method of cooling, compound consumption is reduced. Various constructions and densities are available for specific applications.
For further information circle No. 135 on literature request card on p. 32B

BRAZING STRIP: To simplify the brazing of steel joints the American Silver Co., Inc., is now manufacturing low-carbon steel strip clad with silver brazing alloy on one or both sides, in any thickness ratio and melting range, to suit the requirements of each particular brazing application. As the steel surface is precoated evenly with the brazing alloy, no preplacements are necessary, and every joint is assured of a complete and uniform spread of alloy. Joint surfaces, being pre-diffused with the silver brazing alloy, eliminate the need of such preplacements as wire rings, sheet washers and blanks, and thus reduce considerably the tedious cleaning and fluxing operations before brazing. The heating cycle is reduced, since there is no need to depend on capillary flow to distribute the brazing alloy.
For further information circle No. 136 on literature request card on p. 32B

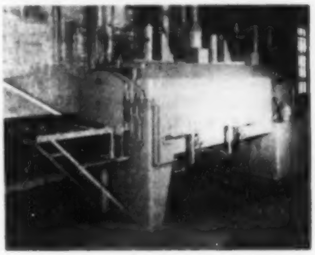
WASHING AND PICKLING MACHINE: A new cleaning machine, developed by The R. C. Mahon Co., is of particular interest to plants manufacturing products with porcelain enamel finishes. The process is continuous through all operations: emulsion cleaning, clear water rinse, alkaline cleaning, three-stage water rinse, sulphuric acid bath, acid water rinse, nickel sulphate bath, sodium cyanide neutralizer, borax neutralizer



rinse, and hot air dry-off. Tanks and tunnel housing are of mild steel except in areas where corrosive materials are in contact or corrosive fumes prevalent. In these areas stainless steel is employed, or the mild steel is lined with lead or rubber.
For further information circle No. 137 on literature request card on p. 32B

PRECISION TUMBLING: Large quantities of parts are precision finished at one time in the new tumbling machine recently developed by the Roto-Finish Co. This machine incorporates many new features that make its operation more automatic and enable the operator to work in greater safety. It is push-button operated, having all controls conveniently located on one compact panel. Once the machine is started, the automatic timer will stop its operation any time from 0 to 20 hr. without further attention. It also has a 5-hp. variable-speed power unit with a remote control handle for adjusting the speed of the cylinder from 10 to 30 rpm.
For further information circle No. 138 on literature request card on p. 32B

FURNACE: The new Ipsen furnace T-600 is a fully automatic, controlled-atmosphere unit for bright production heat treating and is rated at 600 lb. per hr. The unit is especially designed for bright carburizing and bright carbonitriding, although



straight heat treating or annealing can be performed efficiently. Work is automatically loaded, transferred and quenched. The furnace is either gas or electric. The cooling chamber is water jacketed, with automatic temperature control. The quench tank has built-in oil heating and cooling coils, also with automatic temperature control, and, when insulated, can be used for martempering. An airdraulic-operated elevator is used for quenching, and the oil has two-speed propulsion.
For further information circle No. 139 on literature request card on p. 32B

CADMIUM AND ZINC BRIGHTENERS: Manufacturers, who must change their plating specifications from critical chromium, nickel and copper, can attain brilliant finishes with cadmium and zinc brighteners, according to R. O. Hull & Co., Inc. Cadmium brightener is available as a liquid or powder additive and zinc brighteners as liquid additives.
For further information circle No. 140 on literature request card on p. 32B

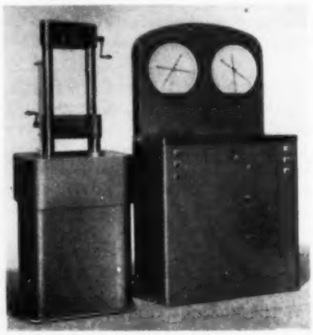
IMMERSION THERMOCOUPLE: Where shop men prefer a thermocouple pyrometer to measure steel bath temperatures in openhearth or electric furnaces, the new equipment just announced by Leeds & Northrup Co. offers exceptional operating con-

Engineering Digest
OF NEW PRODUCTS

venience. The equipment consists of a platinum – platinum 10% rhodium immersion couple and a Speedomax pyrometer with special signaling features. The thermocouple is mounted in a refractory-protected tube, supplied in length from 5 to 12 ft. The fused silica protective tip can be replaced in a few seconds. A reserve supply of platinum wires is located in the tube. To replace the element, the operator loosens two clamps, pulls out wire for a new junction, and replaces the refractory tip, all without disassembling the unit.
For further information circle No. 141 on literature request card on p. 32B

CHROMATE COATING PROCESS: Enthone, Inc., have announced a simplified process for producing chromate coatings on zinc and cadmium. The process is applicable for both zinc plate and zinc die castings. From 1 to 2 oz. of salts is used per gallon of water. The mixture is operated at room temperature, and after immersion for a few seconds, an adherent chromate coating is produced. No elaborate controls are necessary.
For further information circle No. 142 on literature request card on p. 32B

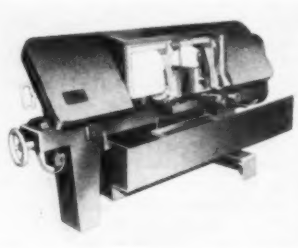
TESTING MACHINE: An improved, low-cost universal testing machine of 12,000-lb. capacity is announced by Baldwin-Lima-Hamilton Corp. The



new Model 12-H has many of the features of larger Baldwin testing machines. One is that the hydraulic loading unit is separate from the indicating and control unit, which isolates recoil from breaking test specimens and permits adjusting maximum or lazy hands with minimum drag. Two ranges are provided: The 12,000-lb. range is graduated in 20-lb. units on a 16-in. diameter indicator dial and a 3000-lb. range is graduated in 5-lb. units. Ranges other than standard are available in any dual combination.
For further information circle No. 143 on literature request card on p. 32B

FINISHES FOR ZINC: United Chromium has added two new compounds for decorative and protective finishing of zinc. The new additions are used to produce corrosion-resisting, chromate-type conversion coatings that are black or olive drab in color. These compounds yield lustrous finishes that meet the corrosion-resistance requirements of most specifications for chromate-type conversion coatings on zinc. The finishes are produced on a metal-conserving deposit of 0.0002 to 0.0005 in. of zinc. The process is a simple dipping one which can be carried out at room temperature.
For further information circle No. 144 on literature request card on p. 32B

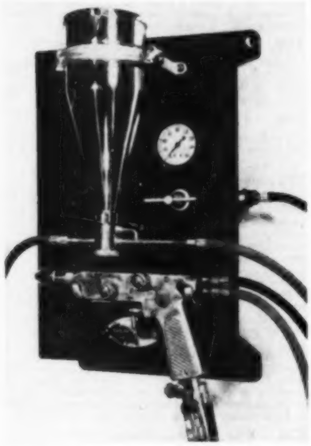
BAND SAW: Metal-cutting band saw "1220" is the latest addition to the line manufactured by the Kalamazoo Tank and Silo Co. It provides accu-



rate production cutting of metals up to 12 x 20 in. It is available in standard or coolant-equipped models, with four cutting speeds (61 to 259 ft. per min.). Standard equipment includes 1-hp. 220/440/60/3 motor and stock stop bar. Dimensions — 87 in. long, 26 in. wide, 25½ in. height to bed.
For further information circle No. 145 on literature request card on p. 32B

SPRAYWELDER: The new Model B Spraywelder of Wall Colmonoy Corp. is a powder metallizing unit which

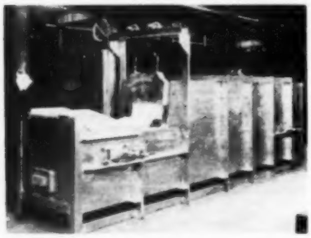
applies uniform overlays of Colmonoy hard facing alloys and then subsequently bonds the overlay to the base metal. New features include lighter weight, greater capacity of air filter,



more positive air and powder control valves, new trigger mechanism and increased cooling chamber in head to insure steadier operation and longer tip life.

For further information circle No. 146 on literature request card on p. 32B

ELECTRIC FURNACE: A continuous electric furnace for heat treating has been designed by Bellevue Industrial Furnace Co. The conveyor belt is



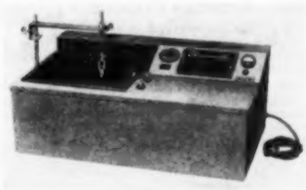
entirely enclosed within the heating zone. With the belt-return enclosed in this manner, a minimum of heat is lost. Water or oil may be used as the quenching agent. Production is 800 lb. per hr.

For further information circle No. 147 on literature request card on p. 32B

BRINELL MACHINE: A newly designed Brinell Hardness Testing Machine which incorporates a throat depth of 24 in. is announced by Steel City Testing Machines, Inc. Made especially for a leading producer of armor plate, this hydraulically operated unit is also adaptable to the requirements of other manufacturers who need a deep-throated hardness tester. This model is mounted on wheels so that it can be rolled out of the way when not in use.

For further information circle No. 148 on literature request card on p. 32B

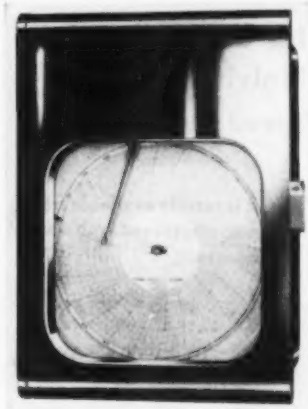
PLATING: Latest addition to Ward Leonard's line of industrial hard chrome plating units is the Model A-50 Chromaster. After only 3 min. plating time, the average life of cut-



ting tools and wear parts has been increased 2 to 10 times with this process. The new bench-mounted plating unit is compact, self-contained, and has a capacity for hard chrome plating metal surfaces totaling 25 sq.in. at the recommended current density of 2 amp. per sq.in.

For further information circle No. 149 on literature request card on p. 32B

RUNNING-TIME RECORDER: A new running-time recorder, just announced by The Bristol Co., records on a chart the operating or "on" time of production machinery and other



equipment. The chart record gives the total "on" time in hours, minutes, and seconds for a given period. "Time off" periods are also shown, as well as the time at which they occurred.

For further information circle No. 150 on literature request card on p. 32B

What's New

IN MANUFACTURERS' LITERATURE

151. Abrasives, Coated

Supplement III to "A Lecture Course on Coated Abrasives" provides a description of coated abrasives and illustrations of acceptable industrial applications. Also includes all of the war-born and war-tested developments in metal grinding and finishing. *Behr-Manning Co.*

152. Alkaline Etching Compound

4-page illustrated bulletin on a new type of alkaline etching compound for all aluminum alloys. Includes case histories. *The Diversey Corp.*

153. Alloy Brazing

Bulletin 54 gives complete story about time, labor and cost-saving made possible by the Alloy Replacement formula. *Handy & Harman.*

154. Alloy Steels

New 16-page, pocket-size booklet entitled "Republic Alloy Steels and How to Get the Most Out of Them" contains seven case histories selected from widely varied fields to demonstrate the versatility of alloy steels. *Republic Steel Corp.*

155. Alloys, Nickel

New technical bulletin T-6 discusses resistance of nickel and its alloys to corrosion by caustic alkalies. *International Nickel Co.*

156. Alloys, Nickel

Hastelloy nickel-base alloys are available for fabricating corrosion-resistant screen, cloth and baskets. Also for metal spraying many types of automatic welding and hard-facing. Booklet, "Hastelloy Nickel-Base Alloys", gives full details. *Haynes Stellite Co.*

157. Aluminum

Copy of "Alcoa Aluminum Impact Extrusions" will be sent on request, giving full information on impact extrusion process and service. Shows whole range of shapes for engineering. *Aluminum Co. of America.*

158. Aluminum Forgings

To help you in designing for aluminum forgings, a new book is offered, covering relation of forging design to die sinking and relation of forging design to the manufacturing process. Also a section on metallurgy gives all commercial alloy compositions, physical properties and tolerances. *Aluminum Co. of America.*

159. Arc Welding

Heliwelding, Airco's inert, gas-shielded arc-welding process for all-position welding of aluminum, magnesium, stainless steel, brass and copper is fully described in ADC-709 Catalog 9. *Air Reduction Sales Co.*

160. Belts, Metal

Bulletin 47P illustrates and describes complete line of wire belts for industry. *Ashworth Brothers, Inc.*

161. Beryllium Copper

Helpful engineering information contained in new monthly series of Beryllium copper technical bulletins. *Beryllium Corp.*

162. Bimetal Elements

64-page catalog written especially to help the design and product engineer select the type and size of thermostatic bimetal element best suited to his temperature-responsive device. *W. M. Chace Co.*

163. Blast Cleaning

Bulletin 219 illustrates with photographs and line drawings the new rotoblast turn-style table for airless blast cleaning of castings. *Pangborn Corp.*

164. Bottom Boards, Magnesium

Complete information and price schedule on magnesium bottom boards for maintaining high quality castings and mold stability. Available from stock in 74 standard sizes. *Christiansen Corp.*

165. Brazing Alloys

Standard pricing schedule and torch brazing instructions for silver brazing alloys listed in 4-page leaflet. *American Platinum Works.*

166. Camera, High Speed

"Magnifying Time", a new folder describing high-speed camera capable of 1000 to 3000 pictures per second. Particularly adaptable for close inspection in machine tool operations and also for measuring flow of liquids as in chemical mixers, coolant flow, etc. *Eastman Kodak Co.*

167. Castings, Nonferrous

Armetol, improved impregnant for magnesium alloy, aluminum bronze and other nonferrous castings, is described in bulletin 501. *Archer-Daniels-Midland Co.*

168. Castings, Steel

New bulletin describes Pyrasteel, the chromium-nickel-silicon alloy for resisting oxidation and corrosion up to 2000°F and for withstanding most concentrated or dilute commercial acids and corrosive gases. *Chicago Steel Foundry Co.*

169. Cast Monel

New bulletin contains valuable information concerning production of cast Monel and wide range of desirable physical and mechanical properties obtainable. *Cooper Alloy Foundry Co.*

170. Carburizing of Tubing

4-page bulletin of metallurgical data on carburizing grades of alloy steel tubing. *Babcock & Wilcox Tube Co.*

171. Centrifugal Castings

Two new bulletins, 150 and 151, describe the broad range of component machine parts and assemblies produced by centrifugal casting, using nonferrous metals, including bronzes monel, nickel, aluminum as well as Meehanite, Ni-Resist and special iron alloys. *Shenango-Penn Mold Co.*

172. Cleaning and Buffing

Bulletin 44 contains an interesting discussion of barrel deburring, as well as methods of removing many kinds of burrs from sawing, drilling, milling and stamping operations. *Magnus Chemical Co.*

173. Cleaning and Finishing

Attractive 12-page, well-illustrated catalog A-652 gives the complete story on planning industrial finishing systems and shows many actual installations of cleaning and pickling machines operating in large metalworking plants. *R. C. Mahon Co.*

174. Coatings, Metal

Explanations of high-vacuum evaporation of metals and other solids set forth in detail in new 12-page booklet, "Vaporized Metal-Coatings by High Vacuum". *Distillation Products, Inc.*

175. Combustion Control

32-page catalog 9601 provides a complete manual on flame failure protection for industrial applications. Includes information on new "flame-rectification principle" with installation drawings and comprehensive data on 24 different safeguard systems. *Minneapolis-Honeywell Regulator Co. Industrial Div.*

176. Conveyor Belts

Catalog 31 provides the full story on spiral woven wire conveyor belts and complete conveyor systems, well illustrated with photographs of different types in operation. *Korb-Pettit, Inc.*

177. Copper Alloy Tubes

An extensively illustrated 32-page brochure, "Life Extension for Condenser Tubes", deals with causes of corrosion and means of combating them, as well as choice of materials for condenser tubes. *Revere Copper & Brass, Inc.*

178. Copper and Copper Alloys

New 24-page booklet B-36 discusses corrosive attack on copper and copper alloys. Includes tabulation for relative corrosion resistance of principal types of copper-base alloys. *American Brass Co.*

179. Cutting Oil

New bulletin on "Gulf Electro Cutting Oil" which contains larger percentage of active sulphur ingredient, recommended for toughest machining jobs. *Gulf Oil Corp.*

180. Detergent Cleaners

Bulletin, "Solubilizing Cleaners", describing action of new cleaners which will dissolve not only water-soluble soils but also water-insoluble soils that can normally be removed only by organic solvents; for instance, buffing compounds, greases and pigmented drawing compounds. *Pennsylvania Salt Mfg. Co.*

181. Dynamic Micrometer

New literature on an electro-mechanical instrument for measuring displacement, vibration or movement of a ferrous body to within 0.0001 inch. *Electro Products Labs., Inc.*

182. Electron Microscope

The new table-model RCA electron microscope is described and illustrated in a 12-page booklet. *Radio Corp. of America.*

183. Emulsifier

Attractive, well-illustrated bulletin A-104 describes Emulsifier —Sth, the new coolant-lubricant for cutting, grinding, drawing and stamping. *General Aniline & Film Corp.*

184. Fastener

4-page folder describing adjustable fastener which is in use on industrial machinery and commercial vehicles of all types. *South Chester Corp*

185. Finishes
New 4-page two-color bulletin describes detail the entire line of Iridite finishes for no ferrous metals. Also includes section on Al process chemicals such as bright hardeners f zinc and cadmium plating and other specialti *Allied Research Products, Inc.*

186. Forging Steel
Bulletin 31 "Chemical Composition of All Steels" furnishes helpful information on stainle forging problems and includes specific data chemical composition of alloy steels. *Timk Roller Bearing Co.*

187. Furnaces
New illustrated bulletin SC-152 presents he treating furnaces for the aircraft industry. Co veniently divided into sections on basic aircr components: steel tubing, aluminum and lig metal assemblies, jet and reciprocating engi parts, propeller blades and miscellaneous aluminu forgings. *Surface Combustion Corp.*

188. Furnaces
Literature describing the use of Marshall tubul furnaces for constant and uniform temperatu furnished in types suitable to your needs. Al radial brackets in stationary and compensati types. *Marshall Products Co.*

189. Furnaces
Complete "Buzzer" catalog available describi Buzzer high-speed gas furnaces designed primari for heat treating high carbon and alloy steels a also atmospheric pot hardening furnaces for sa cyanide and lead hardening. *Charles A. Hones, I*

190. Furnaces
Heavy-duty box furnaces that provide unifor temperatures for hardening production tools a described in bulletins HD-341 and HD-441. *He Duty Electric Co.*

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194. Furnaces, Industrial
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195. Furnaces, Melting
Catalog on Heroult gantry-type electric melti furnace with patented roof-ring to assure spee and simple bricking and eliminate skew shap *American Bridge Co.*

196. Gas Analyzer
Further information available on Type 09-12 a new packaged unit vacuum fusion gas analyz used to determine the content of oxygen, nitrog and hydrogen in metals. *National Research Co*

197. Gears
Information on all types of gearing specificatio including Neloy, spur, bevel, mitre, Sykes Herri bone, available in bulletin No. 9, sent on reque *National Erie Corp.*

198. Hardness Numbers
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199. Heat Control
Complete details on operating the Heat Pro for testing combustion conditions in the furna quickly and accurately. Send for booklet, "Co bustion Control for Industry". *Cities Serv Oil Co.*

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What's New

IN MANUFAC

205. High-Speed Steel
Bulletin SL-2036 describes the new, improved tungsten molybdenum high-speed steel, made especially abrasive resistant for taps, twist drills, milling cutters, lathe and planer tools. *Firth Sterling Steel & Carbide Corp.*

206. High-Speed Steel
Full information on performance, heat treatment and other authoritative facts furnished in booklet entitled, "Molybdenum High Speed Steels". *Climax Molybdenum Co.*

207. High-Speed Steels
New booklet, "Why Desegatized", shows how these hi-carbon hi-chrome steels help to cut production costs with thorough carbide distribution providing extra toughness and strength. *Latrobe Electric Steel Co.*

208. Immersion Heating
Bulletin IE-11 gives complete details on how new immersion pots save time and money in melting soft metals. High thermal efficiency for both large and small units provides rapid heat recovery in one-third the time. *C. M. Kemp Mfg. Co.*

209. Induction Heater
Attractive 4-page bulletin, fully illustrated, gives information and detailed specification on 20-kw. induction heater. *General Electric Co.*

210. Induction Heating
For more economical manufacture in designing and redesigning present products, send for copy of "Design and Manufacture for Profit" with full details on Tocco Induction Heating for brazing, hardening, soldering, forging or shrink-fitting. *Ohio Crankshaft Co.*

211. Induction Heating
Bulletin 1440 furnishes full details on the "Checklite" system for safety control through the use of oversized components built into every unit for longer service life and uninterrupted production. *Lindberg Engineering Co.*

212. Industrial Planning
New book 127 tells how you can share in a "Round Table" discussion of planning expansion remodeling or modernization of your plant. *Continental Industrial Engineers, Inc.*

213. Insulation Block
New 4-page folder on Superex block insulation tells economical advantages and lists outstanding properties by means of conductivity and heat loss graphs and recommended thickness table. *Johns-Manville.*

214. Iron, High Chromium
New booklet, "Abrasion-Resistant High-Chromium Iron", furnishes a complete file of the best available information on how to make and use abrasion resistant iron castings most efficiently. *Electro Metallurgical Co.*

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FACTURERS' LITERATURE

215. Magnesium Die Castings
Revealing book, "How Magnesium Pays", gives case studies of the economical uses of magnesium in a wide range of products. *Dow Chemical Co.*

216. Metal Analysis
New brochure describes the operation of the ARL Production Control Quantometer which furnishes direct-reading, pen-and-ink records of quantitative spectrochemical analyses with extra copies, quickly and accurately. Up to 20 chemical elements measured simultaneously. *Applied Research Labs.*

217. Metal Coating
Bulletin entitled "How To Obtain A Grade I Finish On Steel" furnishes full details on special protective coating required by Government Specification JAN-C-490. *American Chemical Paint Co.*

218. Metal-Forming Lubrication
New bulletin 426-B describes how colloidal graphite can solve your lubrication problems in metal-forming operations at temperatures from below zero up to 5000°F. *Acheson Colloids Corp.*

219. Metallograph
12-page catalog describes this completely new all-in-one desk-type unit for metallographic work. *American Optical Co.*

220. Metallography
New research Metallograph, described in catalog E-240, furnishes four different accurate images of same sample for complete identification with bright field, dark field or polarized light. *Bausch & Lomb Optical Co.*

221. Metal-Treating Ammonia
Bulletins available on "Ammonia Installations for Metal Treating", "Effective Use of Dissociated Ammonia", "Carbonitriding of Steel" and "Nitriding Process". *Armour Ammonia Div.*

222. Microcasting
New color-illustrated folder, "Microcast Case Histories", describes microcasting applications for both industrial and defense requirements. *Austenal Laboratories, Inc.*

223. Motors and Generators
10-page illustrated bulletin 2-200 describes the extensive facilities and line of motor generators and other custom-built equipment for industry. *Electric Products Co.*

224. Nickel Silver
Paper dealing with detailed description of proper foundry procedure for production of sound castings from nickel silver. Also specification information. *R. Lavin & Sons, Inc.*

225. Oil Quenching
Catalog V-1146 gives detailed information on self-contained oil coolers, together with easy selection tables. *Bell & Gossett Co.*

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What's New ____

IN MANUFAC

226. Parts, Baskets

Baskets designed for your individual needs in handling parts. All types of trays, fixtures, retorts and carburizing boxes are described in catalog 16. *Stanwood Corp.*

227. Photomicrography

Full information furnished on Aristophot camera with Ortholux research microscope, providing the perfect team for easy, inexpensive photomicrography and photomacrography. *E. Leitz, Inc.*

228. Plating Generators

Catalog MP-700 describes M-G set for electroplating, anodizing, electrocleaning, or electropolishing in either large or small-scale operations. *Columbia Electric Co.*

229. Polishing and Buffing

Bulletin entitled "Acme Straightline Automatic Polishing and Buffing Machines" illustrates and describes a machine for every type of polishing and buffing job. *Acme Mfg. Co.*

230. Potentiometers

Dynalog instruments for control of temperature, humidity, pressure, flow, etc. Details in bulletin 427. *Foxboro Co.*

231. Power Bending Brakes

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What's New

IN MANUFACTURERS' LITERATURE

226. Parts, Baskets
Baskets designed for your individual needs in handling parts. All types of trays, fixtures, retorts and carburizing boxes are described in catalog 16. *Stanwood Corp.*

227. Photomicrography
Full information furnished on Aristophot camera with Ortholux research microscope, providing the perfect team for easy, inexpensive photomicrography and photomacrography. *E. Leitz, Inc.*

228. Plating Generators
Catalog MP-700 describes M-G set for electroplating, anodizing, electrocleaning, or electropolishing in either large or small-scale operations. *Columbia Electric Co.*

229. Polishing and Buffing
Bulletin entitled "Acme Straightline Automatic Polishing and Buffing Machines" illustrates and describes a machine for every type of polishing and buffing job. *Acme Mfg. Co.*

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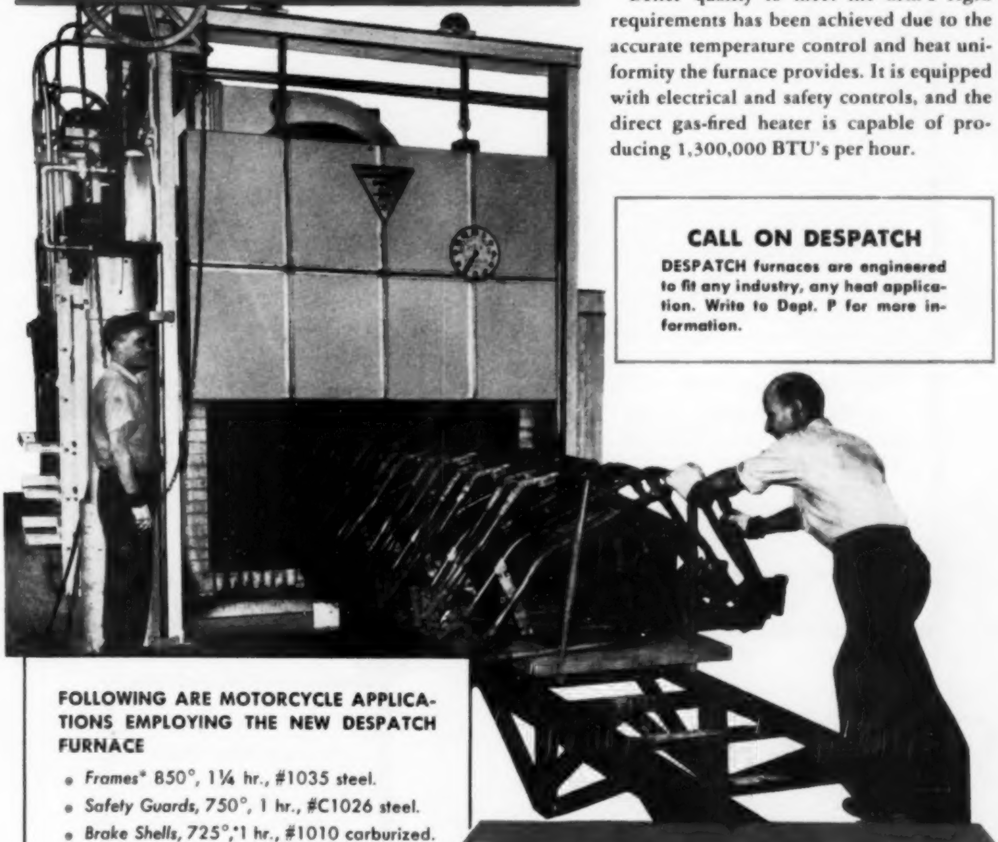
Harley-Davidson meets higher production schedules

DESPATCH

New, Double-end ANNEALING FURNACE Boosts Production 60% over old Methods



THE NATION'S EXCLUSIVE BUILDER OF MOTORCYCLES HAS AGAIN CHOSEN DESPATCH EQUIPMENT . . . Most recent DESPATCH installation is this gas-fired, forced convection air heated type, double-end furnace for annealing motorcycle frames, forks, handlebars, brake shells, etc.

Only steel is handled by the furnace and according to the foreman in charge, the percentage of production increase over the old furnace is 60%. Time saving has been bettered some 60% also, because of the short heat-up period of 20 minutes as compared to an hour with the old furnace. Another time-saving feature is the fact that the furnace can be loaded from either end.

Better quality to meet the firm's rigid requirements has been achieved due to the accurate temperature control and heat uniformity the furnace provides. It is equipped with electrical and safety controls, and the direct gas-fired heater is capable of producing 1,300,000 BTU's per hour.

CALL ON DESPATCH

DESPATCH furnaces are engineered to fit any industry, any heat application. Write to Dept. P for more information.

FOLLOWING ARE MOTORCYCLE APPLICATIONS EMPLOYING THE NEW DESPATCH FURNACE

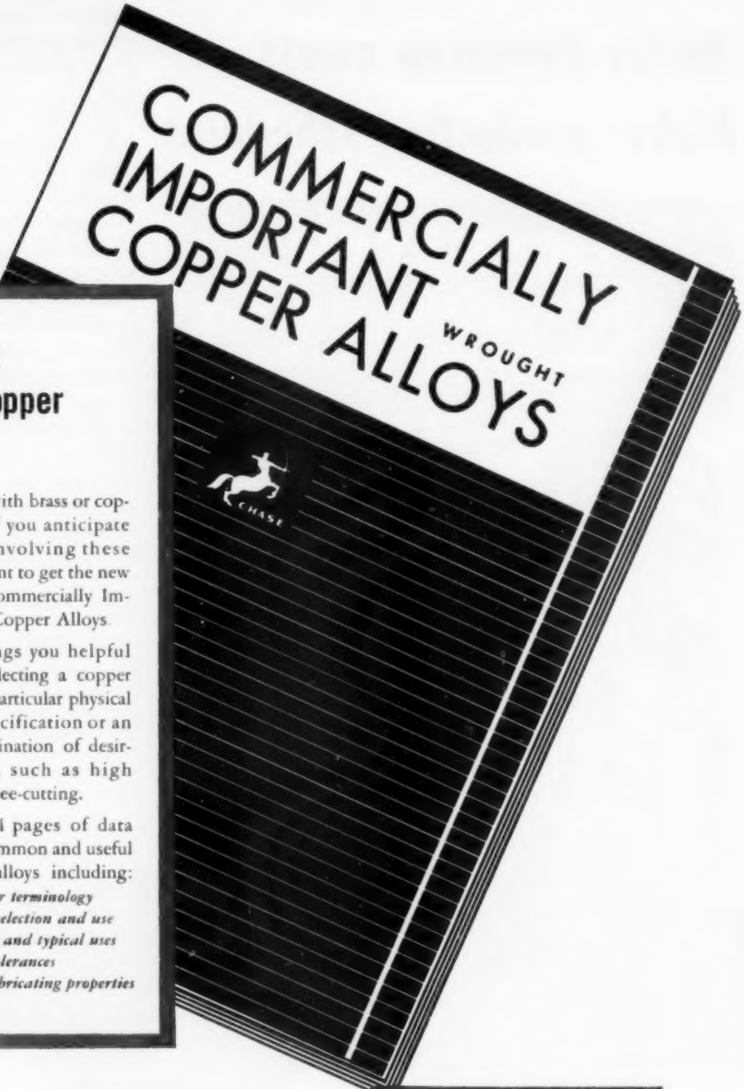
- *Frames** 850°, 1¼ hr., #1035 steel.
- *Safety Guards*, 750°, 1 hr., #C1026 steel.
- *Brake Shells*, 725°,*1 hr., #1010 carburized.
- *Connecting Rods*, 400°, 2 hrs., #1045 steel.
- *Hub Shells*, 400°, ¾ hr., #1010 steel.

* The picture shows a load of motorcycle frames being pushed into the furnace for stress relieving; 15 per load, 5 loads per day.

DESPATCH OVEN COMPANY

Minneapolis Office: 619 S. E. 8th St.

Chicago Office: 4554 Broadway



Fabricating brass or copper alloys?

If you're working with brass or copper alloys . . . or if you anticipate defense orders involving these metals . . . you'll want to get the new Chase book on Commercially Important Wrought Copper Alloys.

This book brings you helpful suggestions for selecting a copper alloy to meet any particular physical or fabrication specification or an alloy with a combination of desirable properties, such as high conductivity and free-cutting.

It contains 124 pages of data about the more common and useful wrought copper alloys including:

- *brass and copper terminology*
- *suggestions for selection and use*
- *forms available and typical uses*
- *weights* • *tolerances*
- *physical and fabricating properties*

Chase BRASS & COPPER

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CHASE 75th ANNIVERSARY 1876 1951

TO GET THIS BOOK

Because of the expense in making this book, we must limit its distribution to those directly concerned with the fabricating of metals. Please send your request on firm letterhead, giving your position or title.

"EDCO Dowmetal BOTTOM BOARDS have resulted in tremendous savings for our foundry"

... says M. C. Crawford of RILEY STOKER CORPORATION

Above photo shows molder at Riley Stoker Corporation placing EDCO Bottom Board on flask preparatory to pressing. EDCO DOWMETAL magnesium boards maintain high quality of castings and reduce rejects because the exclusive grooved and vented design permits escape of gasses and insures mold stability.

RILEY STOKER CORPORATION
FUEL BURNING AND STEAM GENERATING EQUIPMENT
WALKER STREET, DETROIT 7, MICH.

Christiansen Corporation
1515 North Kilpatrick Ave.
Chicago 51, Illinois

May 16, 1951

Attn: Mr. Edw. S. Christiansen, Pres.

Gentlemen:

Before the purchase of EDCO Dowmetal Bottom Boards, we made our own wood boards at a cost of approximately 70c each. We would make 5,000 to 6,000 per year and ended up with a poor quality board. They were much heavier than EDCO magnesium boards, not as easy to handle on the line, and our losses due to burning and breakage were 60 to 80% per year.

In three years time, we have purchased 1,700 of your boards at a cost of \$7,585.00 and our loss in this period has been only \$207.36 or 2.73%.

EDCO Dowmetal Bottom Boards have resulted in tremendous savings for our foundry. It is a pleasure to recommend them to other foundries.

Yours very truly,
RILEY STOKER CORPORATION
M. C. Crawford
M. C. Crawford
Director of Purchases
Detroit Plant

Riley Stoker Corporation is one of the three largest manufacturers of steam generating and fuel burning equipment in the country. EDCO DOWMETAL Bottom Boards are used exclusively in their foundry in the production of gray iron and alloyed casting components.

Photo at left shows molder pouring sand into flask. Photo at right shows molten metal being poured into molds which rest on EDCO Bottom Boards. Gravity conveyor line carries molds on for further processing.

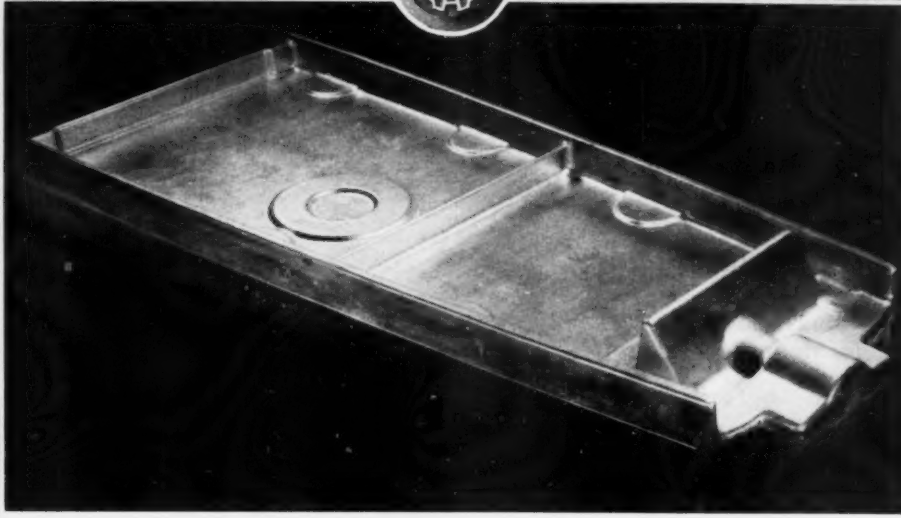
Progressive foundry operators, like Riley Stoker Corporation, are equipping their foundries with EDCO DOWMETAL Bottom Boards.

Made of magnesium, these boards will not warp or break. There are no nails to come out, nothing to break or split—no upkeep! So durable, they can be considered permanent equipment. The many advantages from the use of these boards are effective immediately on their installation.

Write us or phone CApitol 7-2060 today for complete price schedule and list of 74 standard sizes available from stock.

EDCO CHRISTIANSEN CORPORATION

CHRISTIANSEN CORPORATION
1519 N. KILPATRICK AVE. • CHICAGO 51, ILLINOIS
ALUMINUM ALLOY INGOTS • ZINC BASE DIE CASTING ALLOYS



Are you taking full advantage of the constantly growing range of forgings? Typical is this aluminum alloy forging with a projected area of more than 1,000 square inches used in the wing structure of a modern military bomber. Such forgings are today made possible by the use of the largest die forging press in America (18,000 tons). For hammer or press die forgings of aluminum, magnesium or steel, Wyman-Gordon engineers are ready to serve you—there is no substitute for Wyman-Gordon experience.

Standard of the Industry for More Than Sixty Years

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FORGINGS OF ALUMINUM • MAGNESIUM • STEEL
WORCESTER, MASSACHUSETTS
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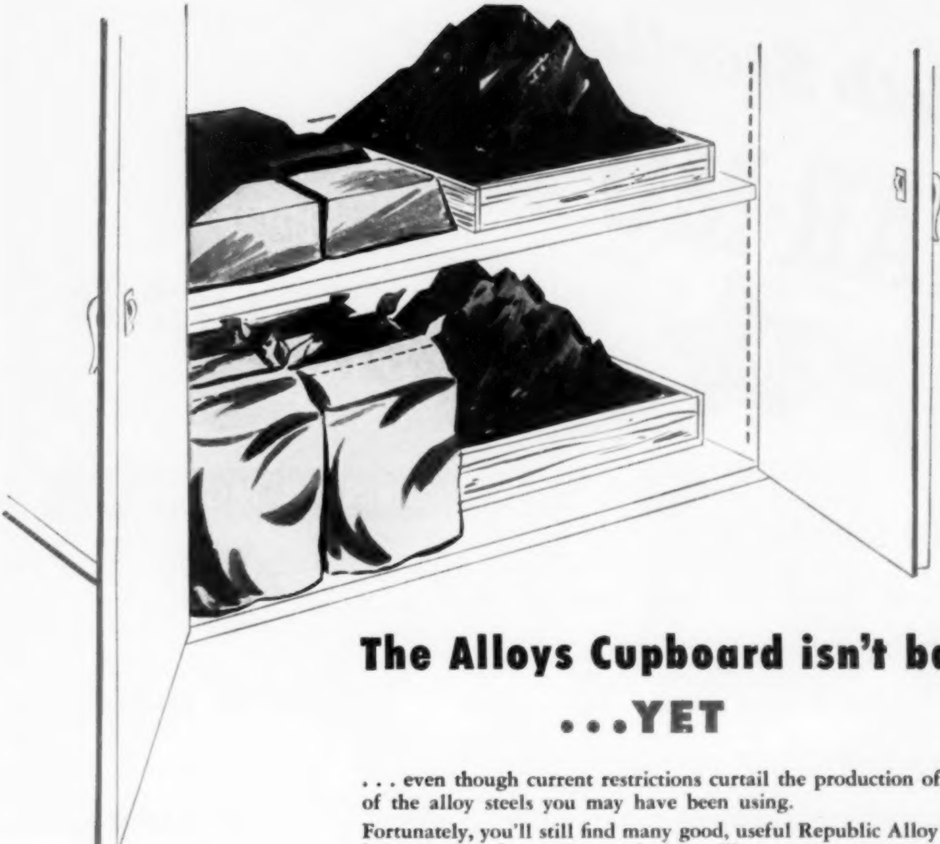

The Alloys Cupboard isn't bare

...YET

. . . even though current restrictions curtail the production of some of the alloy steels you may have been using.

Fortunately, you'll still find many good, useful Republic Alloy Steels being produced . . . alloy steels that will serve most purposes almost as well as those that are victims of the defense movement.

Your problem of selecting the best available alloy steel and putting it to work on your production line will be a lot easier with the help of the team from Republic . . . the Republic Field, Laboratory, and Mill Metallurgists.

In all probability, there is an available alloy steel which will be suitable for your production. A Republic Metallurgist will gladly work with your staff to determine which one is best and how to process it most efficiently.

REPUBLIC STEEL CORPORATION
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LAB MILL FIELD
3-DIMENSION Metallurgical Service

...combines the extensive experience and coordinated abilities of Republic's *Field, Mill* and *Laboratory* Metallurgists with the knowledge and skills of your own engineers. It has helped guide users of Alloy Steels in countless industries to the correct steel and its most efficient usage. IT CAN DO THE SAME FOR YOU.

Republic
REPUBLIC STEEL
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Other Republic Products include Carbon and Stainless Steels—Sheets, Strip, Plates, Pipe, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing

Photo—Chicago Aerial Survey

the wheelco recorder

Here's the Central Manufacturing District of Chicago—where more than 360 industries, concentrated in less than 1½ square miles, manufacture thousands of different products. Yes—here where production records are made and kept—the Wheelco Capacilog is invaluable for measuring, indicating, controlling and recording electrically measurable variables.

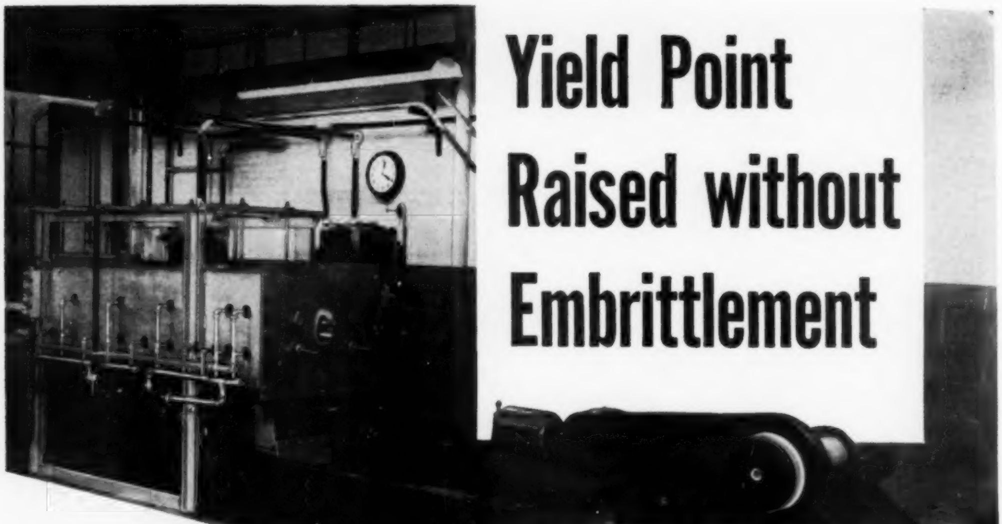
Specify the Wheelco Capacilog, a deflection type strip chart recorder that gives you accuracy to ¼ of 1% of total scale—suppressed scales with a built in reference point—Thermocouple Break Protection that completely eliminates "residual error". Capacilogs are built for use with thermocouples and resistance thermometer measuring elements; as single or multipoint recorders, and with six different control combinations including pneumatic and electric proportioning types.

Assembly line production and simplicity of construction make it possible to deliver most models within 20 days.

instrumentality When you specify Wheelco you specify Instrumentality—Wheelco's ability to design and build efficient and economical instruments to fulfill your needs for accurate and dependable control and recording.

Wheelco Instruments Company, 835 W. Harrison Street, Chicago 7, Illinois

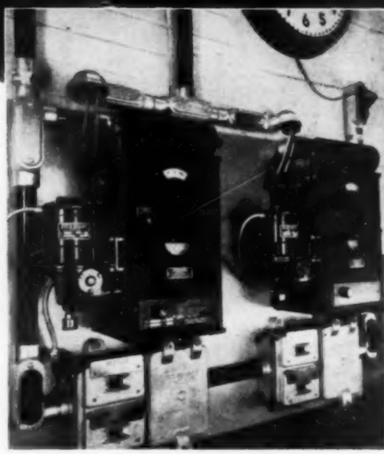
wheelco *electronic controls*



Yield Point Raised without Embrittlement

Foxboro-equipped automatic controlled-atmosphere carburizing furnace and quenching tank at Crouse-Hinds Company, manufacturers of electrical products, Syracuse, N. Y.

These Foxboro M-4000 Potentiometer Controllers automatically and reliably hold carburizing temperatures within ±2.5°F. at Crouse-Hinds.



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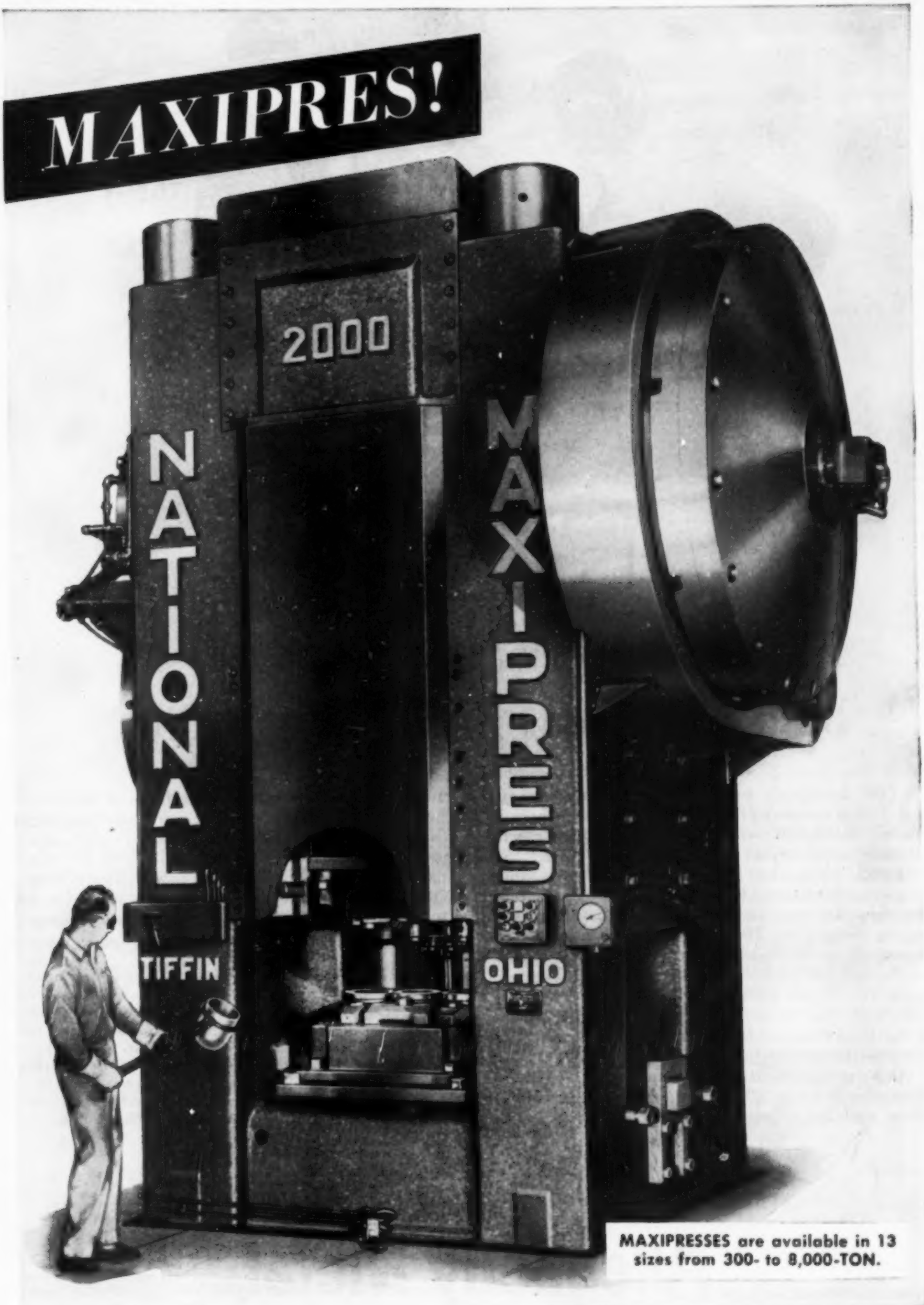
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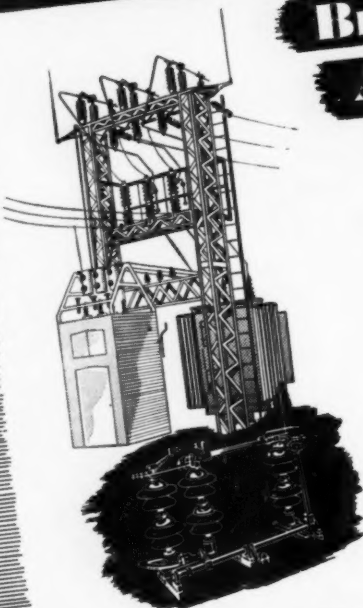

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Increasing Endurance of Magnesium Castings by Surface Work

By George H. Found
Manager
Technical Service and Development
Magnesium Division
Dow Chemical Co., Midland, Mich.

Cold working the surface of metals to improve fatigue strength has been an intriguing subject of study for 25 years, and in the last ten, such treatments have become a common manufacturing operation among steel users. They have extended the life and usefulness of many parts. Automobile springs and gears, railroad axles, and other steel articles highly stressed by alternating loads, are shot-peened or surface rolled as a common practice. Typical results for peening S.A.E. 1020 steel are quoted by H. F. Moore which show that shot peening increased the life of test specimens in reversed bending by as much as 100-fold for stress levels above 37,000 psi. Increase in the allowable working stress, due to the shot peening, was found to be of the order of 33% for the steel studied.

Until recently such strengthening treatments have not been practiced successfully on light metals to any significant extent. A possible exception to this may be the experience of George Sachs who applied a surface-rolling treatment to the hubs of magnesium propellers in Germany in the 1930's. According to his description in *Metals and Alloys* for January 1939, a cluster of three small rolls with $\frac{1}{16}$-in. working faces were forced against the rotating part at a pressure of about 150 lb. It appears that Sachs partially counteracted erosion and high stress concentration effects in the propeller hubs and, thereby, improved the fatigue life of the hubs 80 to 200%.

Other experience with magnesium has included shot-peening treatments of the type used for steel in a collaborative project between J. O. Almen of General Motors Corp. and The Dow Chemical Co.* Treated test pieces were tested in rotating-beam fatigue machines. The results are shown in Fig. 1. In these experiments the peened test pieces have fatigue strengths as much as 60% below the polished pieces, which is in great contrast to the beneficial effects on steel.

Machined, as well as machined-and-polished, test pieces were surface rolled in the General Motors laboratories and tested in the Dow laboratories. These showed that fatigue properties of the machined, polished, and rolled pieces were 10 to 15% higher than for the machined and polished specimens. Surface-rolling the machined (unpolished) pieces gave results practically identical to those from machined and polished surfaces.

From the foregoing experiments, it is evident that magnesium does not respond to conventional shot peening in the same way as steel. Consequently efforts were made to determine why, and to evolve treatments suitable for magnesium. These have been described very briefly in an article by the present author in *Metal Progress* for December 1949, p. 838.

Theory — There are three conceivable ways by which mechanical surface treatments can improve fatigue properties, acting singly or in combination. One is by inducing residual compressive stresses which counteract the tensile stresses applied in service, thereby lowering the net stress in the vulnerable surface regions. The second is by favorably altering the surface layers so that sources of stress concentration on and near the surface are rendered less effective. The third is by work hardening (and thereby strengthening) the cold worked surface layers.

Irrespective of the relative importance of each of these factors, there are certain requirements in the metallographic structure that must be met if the fatigue properties of magnesium are to be improved: The surface layers must be free of incipient cracks and flaws; they must be continuous, metallurgically, without intersecting porosity or other voids.

A photomicrograph is shown in Fig. 2, normal to the surface of a cast magnesium test piece which was shot-peened according to steel

*R. L. Mattson and J. O. Almen, "Effect of Shot Peening on the Physical Properties of Steel", Final Report, Part II, O.S.R.D. No. 4820, National Defense Committee of O.S.R.D., War Metallurgy Division, 1945.

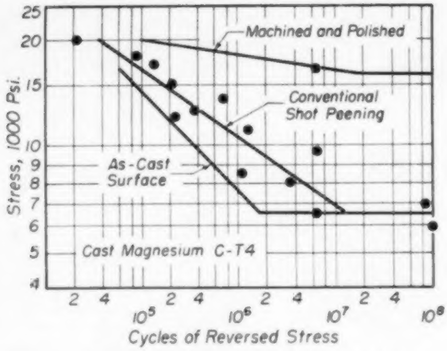


Fig. 1 — Fatigue Tests in R. R. Moore Machine of Cast C-T4 Magnesium Alloy Test Pieces in Three Different Surface Conditions. (Mattson and Almen.) Plotted points are for peened specimens only. Peening conditions: 0.011-in. arc height, 0.018-in. shot. Nominal composition of alloy is 9% Al, 2% Zn, 0.1% Mn, balance Mg

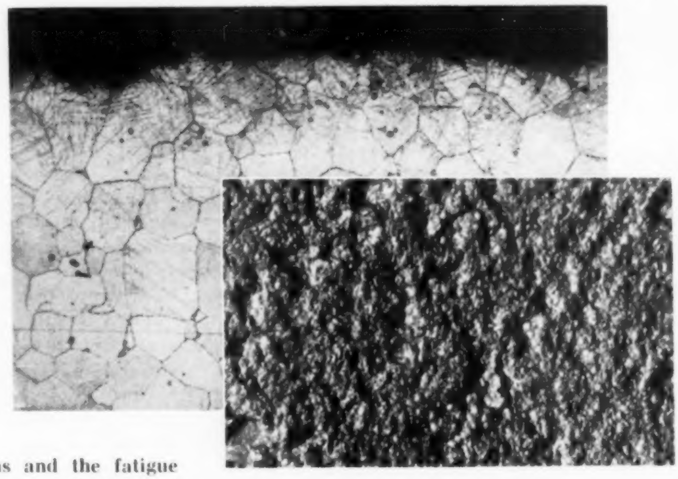
gravity while dropping 24 to 48 ft., were found to work the surface layers intensely to depths of 0.030 in. and more. The surface layers were not cracked. Results are shown in Fig. 3. The shot used are over 12 times the diameter and 1600 times the mass of the shot used for steel. The basic nature of the cast surface is eradicated, yet it is not pitted.

Plate-bending fatigue tests have been performed on specimens of the type shown in Fig. 3e on p. 120 of "Metals Handbook" (1948 Edition). (Plate-bending fatigue tests show the closest correspondence of all the standard laboratory tests to service results of magnesium.) Results are assembled in Fig. 4.

Various surface finishes for cast H-T4 alloy are represented. Peening with large shot strengthens the metal to a superior degree. Of particular note is the similarity of fatigue curves after $\frac{3}{16}$-in. shot peening, whether the surface was previously machined or as-cast. This suggests that a saturation is reached for this *type* of surface-working beyond which it is difficult to improve without basic change in method. Also of interest is the finding that polishing does not improve fatigue properties.

Other methods for inducing the same beneficial surface by techniques which might be more suitable for certain production operations were also studied. A rubbing or burnishing technique was evolved which complements the

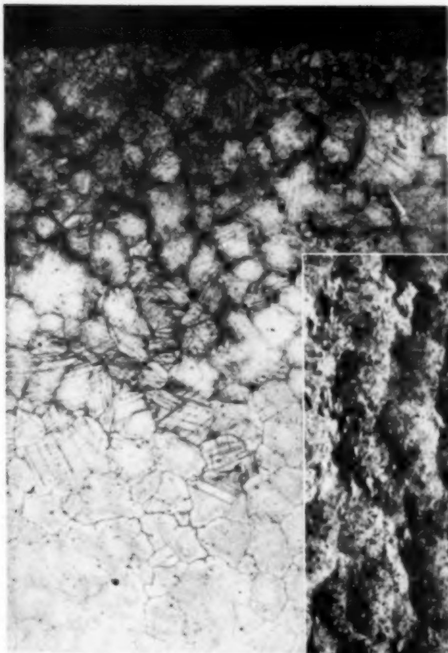
Fig. 2 (below) — Section at 50 ×, Normal to Cast H-T4 Alloy Panel, and Surface at 6 ×, Shot Blasted With 0.016-In. Shot. Intense cold worked layer only 0.003 to 0.005 in. deep, associated with cracks and flakes. Nominal composition of alloy: 6% Al, 3% Zn, 0.2% Mn, balance Mg



practice — that is, with high-velocity, small-diameter shot. The depth of visible surface working is 0.003 in. The surface exhibits irregular contours, surface cracking and spalling. Figure 2 also shows the pock-marked or pitted condition. The surface has deteriorated instead of strengthened; the surface layers have been overworked or deformed beyond their ability to absorb energy (as evidenced by the local incipient failures), and yet the amount of energy applied to the surface is small, as indicated by the shallow surface working.

From these observations and the fatigue tests plotted in Fig. 1, it was concluded that beneficial treatments must prevent surface deterioration and yet retain relatively high applied-impact or surface-working forces. Experiments were therefore conducted to determine if the conventional peening treatments could be altered.

Various kinds of shot were tried, including glass and plastic, but without avail. Heating the shot and warming the surfaces of the metal also gave no success. A practical solution was obtained by a technique involving high forces but without the high-velocity impacts: Hardened steel shot, large in diameter, accelerated by



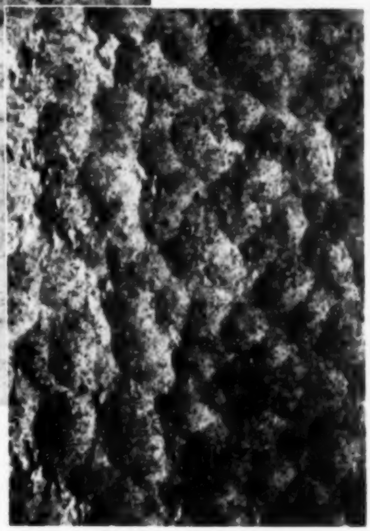


Fig. 3 — Views Corresponding to Those in Fig. 2 When Peening Is Done by $\frac{3}{16}$-In. Shot Falling 36 Ft. Surface is dappled in appearance; cold worked layer is at least 0.050 in. deep

peening treatment; it seems quite suited to machined surfaces, while shot peening can be used on unfinished or as-cast surfaces.

Surface rubbing cold works or induces energy into the surface of the metal. Surface cracks and other flaws are not formed under proper treatment. Cold work of metal at the surface is deep and intense.

TOOLS FOR THE OPERATION

A spherically tipped tool is used, designed for mounting either in a fixed or in a spring-loaded position in a tool stock. Dimensions of the tool tip are determined within limits by the contour of the work, and are between ⅛ and 1 in. diameter. If the tool is in a fixed or spring mounting, it is loaded enough to depress it into the work between 0.004 and 0.015 in. beyond touch contact. The tool is then traversed across the work in a shaper or lathe. The speed of translation of the tool, within the limits of recommended machining practice for magnesium alloys, seems to have an undetectable effect on the results. Traverse of the tool across the work is maintained around 0.006 in. per stroke, so complete and uniform coverage and a slight overlapping is obtained. In order to get intensive and general plastic deformation without exceeding the local yield or shear strengths at the surface of the metal, thus causing tearing, scoring or scuffing, a relatively heavy-grade machine oil lubricates the working surface. A hardened steel ball, obtained from a bearing manufacturer, mounted in a tool shank as shown in Fig. 6 (page 54) has been found most suitable. Flats worn on the rubbing surface of the ball can be easily rotated away from the point of contact at periodic intervals.

Close visual inspection of the resulting surface is one way to control the variables involved in this treatment. The surface must finish bright without laps, tears, or discontinuities. Furthermore, there must be complete and uniform working without grossly defined ridges. A typical example is shown in Fig. 5, on the next page, representing one of the cast panels tested for bending fatigue.

A photomicrograph through a section after this treatment had been applied is also shown in Fig. 5. It will be noted that the surface is flawless and that a zone of intense working

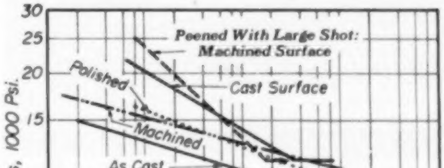
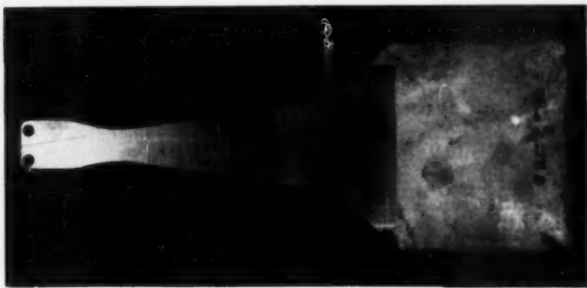


Fig. 4 — Endurance Limit of As-Cast H-T4 Panels Is 8000 Psi. but After Machining and Polishing It Is 10,000. If cast or machined surface is peened with $\frac{3}{16}$-in. shot falling 36 ft. the endurance limit is 12,000 psi. (top two lines)



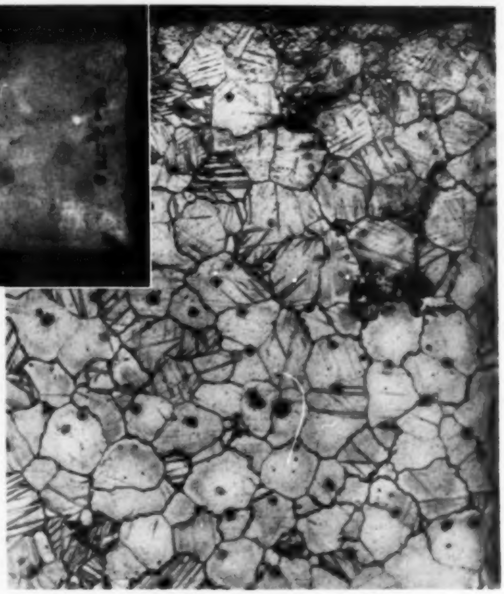


Fig. 5 — Cast H-T4 Which Has Been Ball Burnished, Cold Working 0.030-In. Surface Layer Heavily Without Causing Flaws. Acetic picral etch, magnified 50 ×. Panel is half size, being 7½ in. long

exists to a depth of 0.030 in. and fades out at about 0.080 in.

Panels of the type shown in Fig. 5 were tested in fatigue, with results shown in Fig. 7. For purposes of comparison, our best results from surface rolling are shown. (This selection is similar to that used by Sachs; confirming other comparisons we have made, the compression by surface rolling does not develop the fatigue properties induced by the combination of compression and rubbing or smearing by the hard steel ball.)

Summary — Fatigue tests run according to our best present methods of fatigue testing have shown that surface working as described improves fatigue properties quite significantly. Several hundred laboratory fatigue tests on standard commercial magnesium casting alloys have verified this statement.

It is appreciated that the application of such treatments on a production basis frequently involves circumstances which are not included in the right degree in laboratory demonstrations. Such is undoubtedly true for the above treatments. Phenomenal improvements may be possible if optimum production methods can be developed. The experience of Bendix Aviation Corp. in applying these treatments, on a production basis, to aircraft wheels is a case in point, and will be described in a subsequent article by W. H. DuBois of that firm's staff.

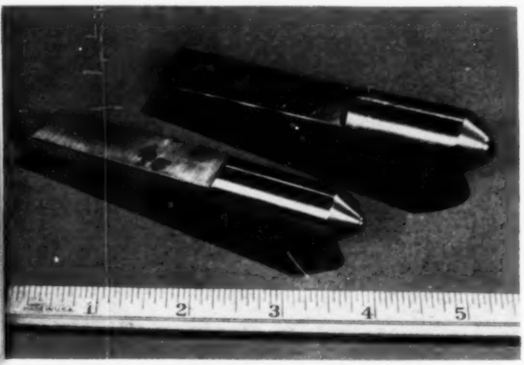
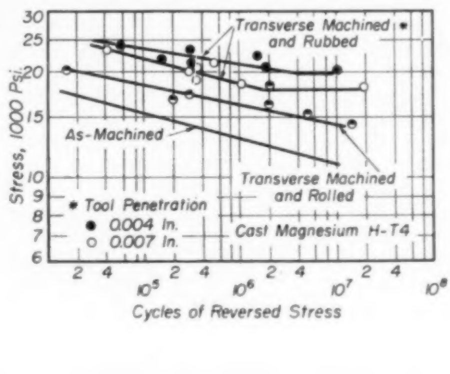


Fig. 6 — Basic Tool Design for Surface Rubbing

Fig. 7 — S-N Fatigue Bands for Cast H-T4 Magnesium Alloy With Prepared Surfaces. Aggregated results from several hundred tests on a variety of commercial magnesium alloys and heat treatments indicate that alloy and heat treatment have no discernible influence on these tests



885° F. Embrittlement of the Ferritic Chromium-Iron Alloys

By J. J. Heger
Research Associate
Research & Development Division
U. S. Steel Co., Pittsburgh

THE FERRITIC STAINLESS STEELS — that is, steels containing over 12% Cr — when heated for long times in the temperature range of 700 to 1000° F. and cooled, increase in hardness and decrease in ductility (when tested at room temperature). These changes in properties are induced most pronouncedly at 885° F., and consequently this phenomenon has been called "the 885° F. (475° C.) embrittlement". As far as is known, its cause never has been definitely established and there is no satisfactory method for eliminating it. However, the subject has been studied intensively, and from the results of the various investigations which have been made, several theories have emerged.

In view of this interest, a survey of these previous investigations has been made. Based on the established facts, a theory of the nature of the embrittlement is proposed.

General Characteristics—The 885° F. embrittlement in ferritic stainless steels is characterized by an increase in strength and hardness, decrease in ductility, and also by changes in electrical resistivity, magnetic properties, corrosion resistance, and microstructure. It should be noted immediately that all data reported (except as specially noted) are from tests made at room temperature, not at 885° F.

Newell's[1] data, plotted in Fig. 1, illustrate the effect of temperature on the room temperature hardness of a 27% Cr alloy heated for three different periods of time. As is evident, the temperature for maximum hardness increase is near 885° F. and, as the holding time increases, the temperature for maximum hardness is lowered slightly. Bandel and Tofaute[2] find that the hardening is proportionate to the chromium content (Table I) being inconsiderable in a 16.3% Cr alloy, but very important in 23.4 and 30.4% Cr alloys. They also find a maximum at 932° F., somewhat higher than given by Newell.

Newell's study of the effect of time at 885° F. on the room-temperature tensile properties of a 27% Cr alloy (Fig. 2) shows that the tensile and yield strength increase and the elongation decreases with time.

Riedrich and Loib[3] report on the effect of temperature and chromium content on the ductility of a series of chromium alloys after heating for 1000 hr., as measured by the bend test (Table II). Such heating at 885° F. is detrimental to alloys as low in chromium as 16.7%, and a 19.4% Cr alloy has no bend ductility left at all after 1000 hr. at 842 or 885° F. The 19.4% Cr alloy is slightly embrittled at higher and at lower temperatures; the 23.8% Cr-Fe is entirely embrittled after 1000 hr. at 752 or 932° F.

Similar results were recorded by Bandel and Tofaute[2] for two 17.5% Cr, 0.04% C alloys, containing 0.04 and 0.17% nitrogen, respectively, when tested in notched-bar impact. Heating at 572 or at 1112° F. for 1000 hr. gave metal with about 24 m.-kg. per sq.cm. in impact. An equal time at 752 or 932° F. reduced this value to about 6. A minimum value of impact (about 2) and a maximum hardness (about 250 Brinell) was recorded after 1000 hr. at 860° F. The figures just given were scaled from curves wherein it appeared that the course of events was not influenced to a notable degree by the high nitrogen in one of the alloys.

All of the property changes above described were evidenced by measurements made at room temperature after exposure of the metal at or near 885° F. Some recovery of the effects of such embrittlement is noted by property changes at the temperature of embrittlement, as is illustrated by Fig. 3 (Riedrich and Loib[3]) and Fig. 4 (Olzak[4]). Figure 3 shows that, when tested at 975° F., a previously embrittled 24% Cr iron has notch toughness of 8 m.-kg. per sq.cm. Likewise Fig. 4 from Olzak's work[4] shows that a 27% Cr-Fe, embrittled by 500 hr. at 885° F., has about 30% reduction of area and 15% elongation, when tested at 885° F.

Riedrich and Loib[3] indicate that physical properties also are affected by the embrittlement. Table III gives their determinations of hardness,

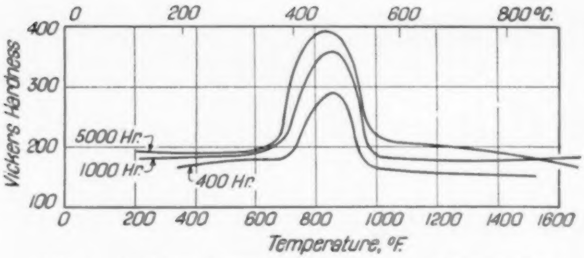


Fig. 1 — Hardness Surveys on Bars After Prolonged Heating in a Temperature Gradient. (Newell[1]) Analysis: 0.20% max. C, 1.50% max. Mn, 0.25% max. S and P, 0.75% max. Si, 26 to 30% Cr, 1% max. Ni, 0.2 to 0.25% N

specific gravity, and coercive force, all of which increase with increasing time at 885° F., whereas electrical resistance decreases.

Corrosion resistance, as measured by weight loss in boiling nitric acid, decreases if the material has been heated in the embrittling temperature range — a phenomenon reported by various investigators. Bendel and Tofaute[2] indicate also that this damage increases with increasing chromium content. For example, a 17% Cr-Fe, heated 1 hr. at temperatures below 750 and above 1125° F., has a weight loss in nitric acid of about 0.5 g. per sq.m. per hr.; this figure about triples (1.3) after heating 1 hr. at 850° F. On the other hand, 30% Cr-Fe which resists nitric acid almost perfectly has the high corrosion rate of 5 g. per sq.m. per hr. after heating 1 hr. at 850° F.

Table I — Brinell Hardness of Cr-Fe Alloys (0.05% Cr) After 500 Hr. at Indicated Temperatures[2]

Temperature	16.3% Cr	23.4% Cr	30.4%
572° F. (300° C.)	142	152	167
752° F. (400° C.)	165	157	180
932° F. (500° C.)	165	277	333
1112° F. (600° C.)	136	150	170
1292° F. (700° C.)	130	150	166
1472° F. (800° C.)	120	150	164

All of the changes described indicate that during heating at about 885° F. some alteration has occurred in the structure of the metal. Accordingly, this alteration should be detectable either by microscopic examination or by X-ray diffraction. Early investigators could detect no significant metallographic changes, but, as techniques and equipment improved, structural changes were reported. For example, Riedrich and Loib[3] reported a grain boundary widening and concluded that the embrittlement was caused chiefly by a precipitation along the grain boundaries. Bandel and Tofaute[2] reported the discovery of a lamellar precipitate in embrittled 18% Cr alloys.

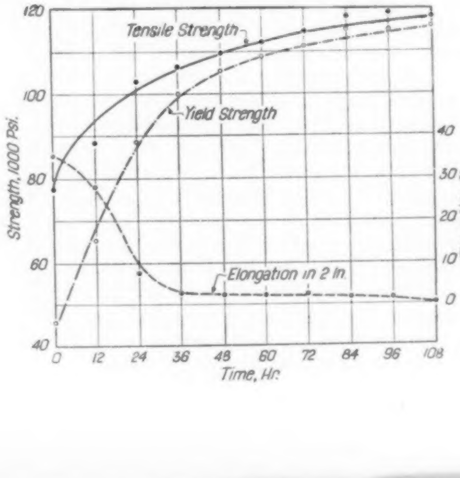
In embrittled metal containing 28 to 35% Cr, they reported a general darkening upon etching which was more pronounced along the grain boundaries. Newell[1] also reported a grain boundary widening, together with a mottled condition of the ferrite in embrittled 27% Cr material.

STRUCTURAL CHANGES OBSCURE

With one or two exceptions, X-ray investigations have failed to disclose any significant change in the structure after heating in the neighborhood of 885° F. Becket,[5] Riedrich and Loib[3] and Bandel and Tofaute[2] reported no change in lattice parameter after embrittlement. Newell[1] could find no change in lattice parameter but reported that an atomic disturbance was indicated by diffused, or widened, diffraction lines in the back-reflection spectra of an embrittled specimen. When drastically cold worked specimens of 27% Cr are heated to 885° F. a phase was precipitated identifiable by X-rays as sigma. (This work was first done by Rutherford[6] and later confirmed by the present author.[7]) Using the same technique, the author has been able to show that sigma phase will form in 17% Cr. Its microstructure is shown in Fig. 5, p. 59.

To summarize, the characteristics of the

Fig. 2 — Effect of Aging Time at 885° F. on the Room-Temperature Tensile Properties of 27% Cr-Fe Alloy. (Newell[1])



885° F. embrittlement are an increase in hardness, tensile strength, and yield strength, and a marked decrease in ductility and impact strength. These alterations are reflected by changes in room-temperature properties, as well as by changes in properties at the embrittling temperature. Changes in electrical resistance, density, magnetic properties and corrosion resistance also occur after embrittlement. These changes in physical and mechanical properties are accompanied, although perhaps at a slower rate, by changes in the microstructure, principally at the grain boundaries, but no significant structural changes have been detected by X-ray diffraction except for specimens drastically cold worked prior to embrittlement.

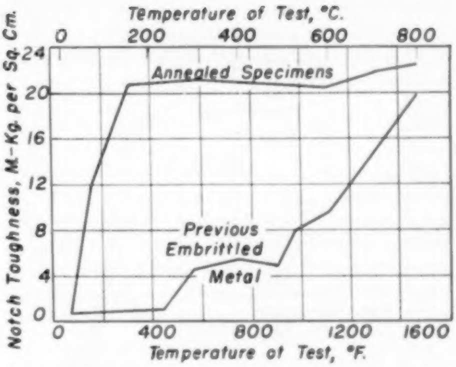


Fig. 3 — Recovery of Notch Toughness of Annealed and Previously Embrittled Specimens of 24% Cr-Fe When Tested at Elevated Temperature[3]

EFFECT OF COMPOSITION

Perhaps the most obvious course to pursue in an attempt to eliminate this temperature effect would be to experiment with alloy additions. Actually, this has been done. The effects of chromium, carbon, titanium, columbium, manganese, silicon, nitrogen, aluminum, phosphorus, and nickel have been studied, but all have shown negative results. The following is a brief description of the effect of several elements.

Table II — Angle of Bend of Chromium Steels After 1000 Hr. at Temperature[3]

Chromium Content	752° F. (400° C.)	842° F. (450° C.)	885° F. (475° C.)	932° F. (500° C.)
14.3%			180	
16.7			160	
17.0		180		
17.7	180			180
19.4	160	Zero	Zero	145
20.1	80			
22.0	30			
23.8	Zero			Zero

Chromium — Bandel and Tofaute[2] investigated chromium-irons up to 70% Cr. Brinell hardness increased greatly after 5000 hr. at 930° F. in all alloys containing more than 17% Cr; the minimum limit for stable alloy may be as low as 12.5%. Specific data are as follows:

Chromium Content	Original Hardness	After 5000 Hr. at 930° F.
20	140	284
30	168	340
40	213	385
50	272	408
60	310	425
70	340	434

A similar investigation by Riedrich and Loib[3] yielded the same general information, that is, as the chromium content increases, the intensity of the embrittlement also increases. The difference in the results of these two investigations lies in the minimum amount of chromium that will result in embrittlement; Riedrich and Loib report 15.5% Cr as the limit, Bandel and Tofaute say 12.5%. Newell[8] has reported the embrittlement of 12% Cr steels containing 0.20% Al (A.I.S.I. Type 405), although Scheil,[9] testing the same material, reported it ductile.

Carbon — The effect of carbon has been investigated by the bend test.[3] Samples with about 23.5% Cr and 0.04 and 0.10% C withstood 10 hr. at 885° F. without losing ductility (bend test = 180°), but lost the ability to bend after 50 hr. at that temperature. Other samples with 0.20 to 0.30% C, capable of bending flat upon themselves originally, cracked upon 140° bend after 5 hr. at 885° F., and lost practically all bend-ductility after 50 hr. The investigators considered the effect of carbon to be small.

Titanium and Columbium — Although the effect of carbon is apparently negligible, both titanium and columbium additions have been

Table III — Changes of Physical Properties of 24% Cr-Fe With Increasing Time at 885° F.[3]

Property	1 Hr.	50 Hr.	500 Hr.	1000 Hr.
Brinell hardness	167	283	322	322
Specific gravity	7.62	7.63	7.64	7.64
Coercive force*	3.2	3.2	4.4	5.4
Electrical resistance†	66	65.5	63.5	62.7

*Oersteds. †Ohms.

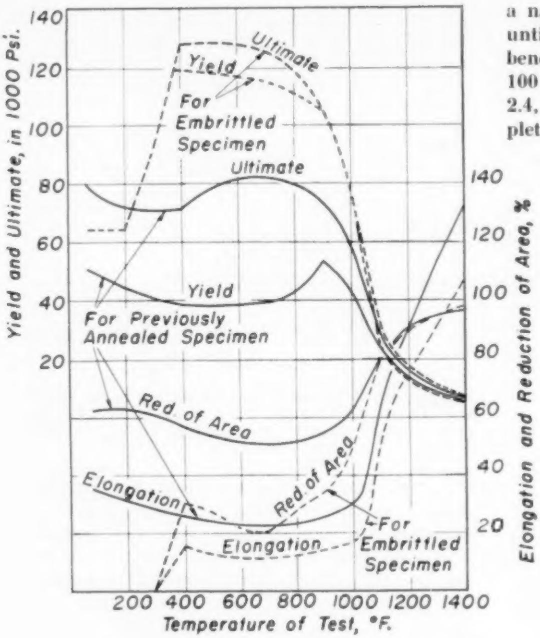


Fig. 4 — Short Time, High-Temperature Tensile Tests on 27% Cr-Fe Samples, *(a)* Annealed or *(b)* Embrittled by Heating 500 Hr. at 885° F.[4]

tried in the hope that their effect might be good, since they prevent intergranular corrosion in the austenitic chromium-nickel steels, low in carbon. However, neither reduces the embrittlement tendencies — rather they intensify it. This intensification has been explained by assuming that these elements, by forming carbides, prevent the formation of chromium carbide and thus free more chromium to take part in the harmful processes.

The specific data on which the above conclusions rest are given by Riedrich and Loib.[3] Experimenting with a 24% Cr-Fe alloy of such a nature that its bend-ductility is not affected until it is heated 10 hr. at 885° F., but whose bend-ductility is completely exhausted after 100 hr., it was found that three alloys with 2.4, 3.3, and 4.5% Cb added, all were completely brittle (bend angle = zero) after 50 hr. at 885° F. All the titanium alloys (0.7, 1.2 and 3.8% respectively) were considerably embrittled in 10 hr. at 885° F., bending from only 30 to 80° before fracture, whereas the titanium-free metal bent completely, 180°.

Molybdenum — Inasmuch as the temperature range for the phenomenon under study is nearly the same as the range of temper brittleness for low-alloy steels, a similarity between the two was assumed. Since molybdenum is a good specific for temper brittleness, additions were suggested for the Cr-Fe alloys. However, its effect is to increase, not decrease, the trouble. For example, 2% molybdenum added to a 29% Cr alloy had a hardness of about 200 Brinell after water quenching from 1470° F., which was increased to 375 after heating 500 hr. at 932° F.[2] Reference to Fig. 1 indicates that a similar alloy without molybdenum would require between 1000 and 5000 hr. at high temperature to be hardened to that degree. This intensifying action of molybdenum has been confirmed by other investigators.

Manganese — Increased manganese up to 3% lowers the embrittlement tendency slightly. Perhaps this effect may be explained by the fact that manganese has caused some austenite to form and, as far as is known, the embrittlement is confined solely to ferrite.

Silicon has almost exactly the opposite effect; that is, 2.8% silicon increases the embrittlement tendency (as measured by bend tests) almost as much as 3% Mn decreases it.[3] The combined effect of silicon and aluminum was

References

1. "Properties and Characteristics of 27% Chromium-Iron", by H. D. Newell, *Metal Progress*, V. 49, May 1946, p. 997 to 1006, 1016 to 1028.

2. "Brittleness of Chromium-Rich Steels at Temperatures Around 930° F.", by G. Bandel and W. Tofaute, *Archiv für das Eisenhüttenwesen*, V. 15, No. 7, 1942, p. 307 to 319. (Brutcher Translation No. 1893.)

3. "Embrittlement of High Chromium Steels Within Temperature Range of 570 to 1110° F.", by G. Riedrich and F. Loib, *Archiv für das Eisenhüttenwesen*, V. 15, October 1941, p. 175 to 182. (Brutcher Translation No. 1249.)

4. "Short Time Elevated Temperature Tensile Properties of Annealed vs. Embrittled 27% Chromium Iron Alloy", by Z. E. Olzak, Rubber Reserve RR 3-2.

5. "On the Allotropy of Stainless Steels", by F. M. Becket, *Transactions* of the American Institute of Mining and Metallurgical Engineers, V. 131, 1938, p. 15 to 36.

6. Unpublished data by J. J. B. Rutherford, U. S. Steel Research Laboratory.

7. "Development of Sigma Phase in 27% Cr-Fe", by J. J. Heger, *Metal Progress*, V. 49, May 1946, p. 976-B. (Data Sheet.)

investigated by Bandel and Tofaute.[2] Both of these elements intensify the embrittlement.

Nitrogen was mentioned as being innocuous earlier in this article when embrittlement was measured by loss in impact strength.

Nickel — With increasing nickel content, the gain in hardness by stay at high temperature (tendency for embrittlement) increases at first, but as more nickel is added and austenite begins to form, it decreases.[2] This twofold effect of nickel is illustrated in Fig. 6.

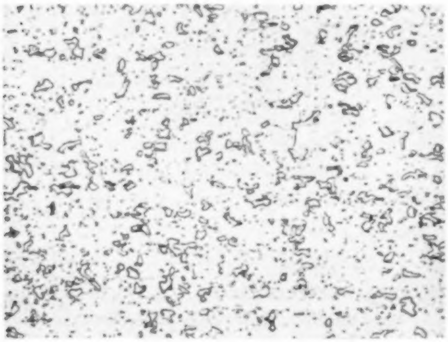


Fig. 5 — 17% Cr-Fe Alloy, Cold Reduced 95.4%, Then Heated 5000 Hr. at 1050° F. Etched with Marble's reagent. Clear particles are sigma phase. 750 ×

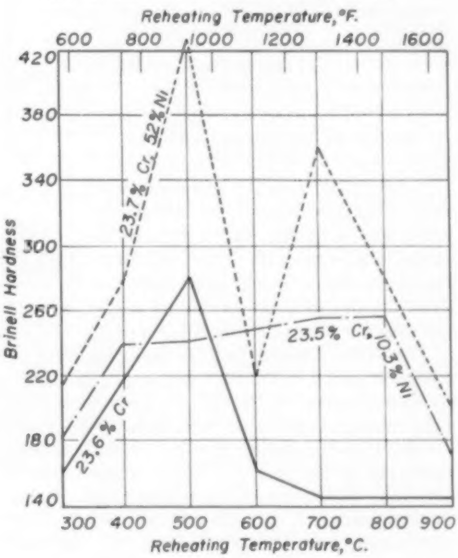
Phosphorus — Bandel and Tofaute[2] investigated three 24% Cr-Fe alloys containing 0.01, 0.20 and 0.68% phosphorus, respectively. Hardness of these alloys after 500 hr. at various elevated temperatures reflected the hardening effect of phosphorus. That is to say, the 0.20% P alloy was consistently about 20 Brinell numbers harder than the 0.01% P alloy; the 0.68% P alloy was about 25 numbers harder than the 0.20% P alloy. These figures were for samples water quenched from 1450° F.

A considerable intensification of the hardening effect of phosphorus occurred if the samples were previously water quenched from 2190° F. Hardness data follow; samples were heated 500 hr. at the temperatures noted.

Heating Temperature	0.01% P	0.20% P	0.68% P
400° C. (752° F.)	150	190	260
500° C. (932° F.)	210	260	455
550° C. (1022° F.)	140	170	240
600° C. (1112° F.)	145	160	210

This pronounced hardening during long reheating after a high-temperature quench has been used to explain the embrittlement as being caused by a phosphide precipitate. However, this explanation is somewhat dubious inasmuch as the above figures show that material containing as low as 0.01% phosphorus will become embrittled (hardens from a normal 150 to Brinell 210 after soaking at 932° F.).

Fig. 6 — Effect of 5 and 10% Ni on Hardness of 23.5% Cr-Fe After Heating 500 Hr. at Various Elevated Temperatures[2]



8. "High Chromium Irons", by H. D. Newell, *Metal Progress*, V. 51, April 1946, p. 617 to 626.

9. "Modified Type 405 Stainless Iron: A Satisfactory Lining for Petroleum Refinery Vessels", by M. A. Scheil, *Metal Progress*, V. 52, July 1947, p. 91 to 102.

10. "Alloys of Iron and Chromium", by V. N. Krivobok, *Transactions* of the American Society for Metals, V. 23, 1935.

11. "An Introduction to the Iron-Chromium-Nickel Alloy", by E. C. Bain and W. E. Griffiths, *Transactions* of the American Institute of Mining and Metallurgical Engineers, V. 75, 1927, p. 166.

12. "The Iron-Nickel-Chromium System", by E. C. Bain and R. H. Aborn, *Metals Handbook*, American Society for Metals, 1939, p. 418 to 422.

13. "The Brittle Constituent of the Iron-Chromium System. I — A Survey of the Limits of the Sigma Phase in the Binary System", by A. J. Cook and F. W. Jones, *Journal* of the Iron and Steel Institute, V. 168, 1943, p. 217 to 226.

14. The Structure of Metals, by C. S. Barrett, McGraw-Hill Book Co., N. Y., 1943, p. 461 to 474.

15. "Stability of Steels at Elevated Temperature", by A. B. Wilder and J. O. Light, *Transactions* of the American Society for Metals, V. 61, 1949, p. 141 to 166.

Heat Treatment — The effect of prior heat treatment was studied by Bandel and Tofaute,[2] who reported it to be small.

"Pure" Iron-Chromium Alloys — Since the additions of alloying elements offered little or no improvement, the hypothesis was advanced that the embrittlement was caused by a minor impurity. However, Becket[5] early reported that even the purest alloys are subject to embrittlement, and this has been confirmed by Krivobok.[10]

In Summary, the effect of composition on the 885° F. embrittlement in chromium steels is as follows:

Chromium	Intensifies
Carbon	No effect
Titanium	Intensifies
Columbium	Intensifies
Molybdenum	Intensifies
Manganese	Lowers slightly
Silicon	Intensifies
Aluminum	Intensifies
Nitrogen	Very slight; intensifies
Nickel	Low amounts, intensify Large amounts, decrease
Phosphorus	Intensifies

NATURE OF THE EMBRITTLEMENT

Inasmuch as alloy additions and heat treatments have no beneficial effect and even the purest iron-chromium alloys embrittle, the cause for the phenomenon would seem to be the precipitation of some phase which is inherent in iron-chromium alloys.

In this connection neither Becket[5] nor Riedrich and Loib[3] believed the precipitant to be sigma phase — although, to date, this is the only intermediate phase which has been found in the iron-chromium system. Becket's main objection to the idea that sigma phase is guilty was that the limits of the alpha+sigma region do not embrace the lower chromium alloys which embrittle. Riedrich and Loib's objection was that sigma phase formed at temperatures above 1100° F., whereas the embrittlement occurred at 885° F.; they believe that embrittlement and the formation of sigma are two separate reactions having no clear relationship to each other.

On the other hand, Bain and Griffiths[11] indicated that the presence of sigma phase in the iron-chromium system offered a possible explanation — a view also shared by Aborn,[12] Krivobok,[10] and by Bandel and Tofaute.[2]

All of these investigators, like Becket, were fully aware that the alpha+sigma boundary limits did not include the low-chromium alloys which embrittle. However, they also recognized that reaction rates are slow in the iron-chromium alloys, and accordingly, they believed that the published boundary limits were not the true equilibrium limits. As Krivobok asks, "Is it not possible that with much prolonged time of heating (approach to equilibrium) the limits of compound (sigma phase) formation may be found to extend far beyond those sketched at present?"

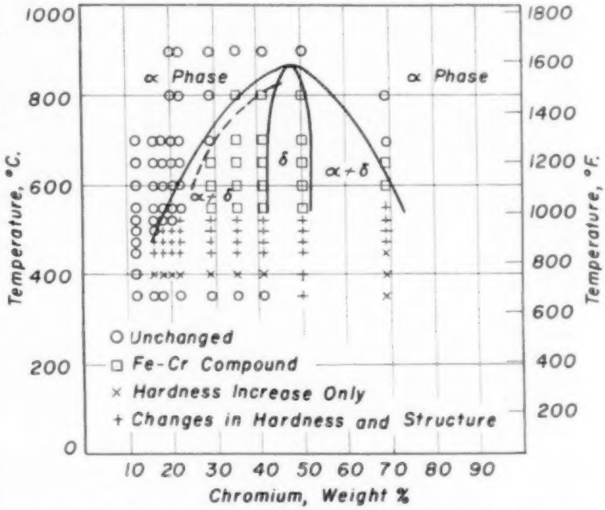


Fig. 7 — Equilibrium Diagram Showing Limits of Sigma Phase and Alpha Plus Sigma on Either Side, Based on Changes in Hardness or Structure After Heating 6000 Hr. at Various Temperatures.[2] Dotted line represents limits of alpha plus sigma as proposed by Cook and Jones[13]

SIGMA MAY FORM IN 17% CR-FE

This view was found to be justified, at least in part, because in the year 1935, when Krivobok published the above statement, the alpha+sigma limit was set at 35% Cr; since that time, results published by Cook and Jones[13] on very pure alloys indicated that it was more like 25% Cr, and Bandel and Tofaute's results[2] (Fig. 7) show sigma phase to form in alloys containing as low as 17% Cr. This diagram is based on the criterion that the alloys which embrittle are within the alpha+sigma region.

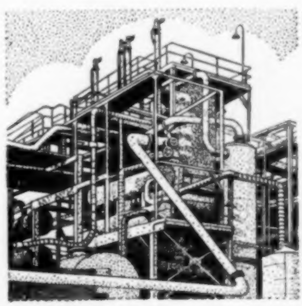
On this basis, Bandel and Tofaute concluded that the embrittlement of the iron-chromium alloys was due to a precipitation hardening process involving early stages in the

formation of sigma phase in much the same manner that the precipitation hardening of aluminum-copper alloys[14] involves the eventual precipitation of the compound $CuAl_2$. They also believed that other precipitates, chromium phosphides for example, might add to the effect. These ideas appear to be quite logical, because they indicate that the 885° F. embrittlement in pure iron-chromium alloys may be explained by the same principles as the theory of precipitation hardening, developed for the nonferrous alloys. For commercial iron-chromium alloys, the mechanism is more complicated because, in addition to sigma phase, other sub-microscopic compounds or phases may form when these alloys are heated at 885° F.

On the basis of this theory, an iron-chromium alloy, capable of embrittlement, when heated in the embrittlement range of temperature undergoes the following reaction:

Alpha phase → transition phase → sigma phase

The transition phase is intermediate in structure between the alpha and sigma, and is coherent, atom for atom, with the matrix (alpha phase). This coherency between two different structures causes large stresses to be set up, and these stresses increase the hardness and cause other property changes peculiar to precipitation hardening. As the transition phase grows in amount, the stresses become larger until they become intolerable; the transition phase then breaks away from the alpha matrix and forms tiny particles of the equilibrium precipitate, namely, sigma phase. This relieves the internal stresses, and softening or "overaging" begins.



In the nonferrous alloys, this mechanism takes place in a matter of hours or days at temperatures just slightly above room temperature. In the iron-chromium alloys, the complete reaction requires a matter of years or tens of years at 900° F.

At temperatures above 1000° F. the iron-chromium alloys will not age harden even though sigma phase can form. This apparent anomaly may also be explained on the basis of the precipitation hardening theory. If, as the theory postulates, the stresses and strains set up by the transition lattice are the cause of the increase in hardness, then no hardening would be expected if the matrix were incapable of being strain hardened at the temperature of precipitation. On this basis, iron-chromium alloys do not embrittle when heated above 1000° F. because, at these temperatures, the matrix is incapable of being strain hardened. (However, if excessive amounts of sigma phase are formed after very long times, the alloys will be brittle because sigma phase itself is brittle.) The softening which occurs when embrittled specimens are heated above 1000° F. may simply be a strain relief or creep-relaxation process, or it may be caused by solution of the transition phase nuclei formed at 885° F. and which, because of their minute size, are unstable at temperatures above 1000° F.

SUMMARY

The 885° F. embrittlement of the ferritic stainless steels is characterized by an increase in hardness, tensile strength, and yield strength, and by a decrease in ductility and impact strength. Changes in electrical resistance, density, magnetic properties and corrosion resistance also occur. These changes in mechanical and physical properties occur after the steels have been heated in the temperature range of 700 to 1000° F., and have been observed in tests made at room temperature and in tests made at the embrittling temperature.

Precipitation of one or more constituents has accompanied these changes in physical and mechanical properties. However, a positive identification has not been made by analysis of X-ray diffraction spectra except when specimens drastically cold worked prior to embrittlement were used. In such specimens, the precipitate has been identified as sigma phase (iron-chromium compound).

Neither additions of alloying elements, variations in heat treatment, nor elimination of impurities have prevented these gradual changes in the hot alloy.

For pure iron-chromium alloys, the embrittlement is believed to be caused by the precipitation of sigma phase (or some transitory phase that precedes the formation of sigma). In commercial iron-chromium alloys, the precipitate that forms during heating in the range of 700 to 1000° F. may include nitrides, phosphides, and carbides, as well as sigma.

Robert B. Schenck

Retiring as
Chief Metallurgical Engineer
for Buick Motors

THIRTY-FIVE YEARS as head of the metallurgical department of a large and progressive unit of the American automotive industry can mean only that the man has a substantial foundation of professional information, a quality of leadership which attracts and holds competent associates, a mind eager for new ideas, and a spirit undismayed by obstacles. Such a man is ROBERT B. SCHENCK, chief metallurgical engineer of Buick Motors Division of General Motors Corp., known affectionately as "R B" to his co-workers. His efforts and achievements as a metallurgist, scholar, and supervisor have continually inspired them to the highest ideals in their work. This respect and admiration is also shared by his many, many professional acquaintances throughout the metal industry.

ROBERT SCHENCK was born in Beacon, N. Y., on June 21, 1886. He was educated in Boys High School in Brooklyn, and graduated from Lehigh University with the degree of Electrometallurgist (1909). Shortly thereafter he went to Homestead, Pa., and before long was serving as a foreman in the armor plate department of Carnegie Steel Co. In the winter of 1914-1915 he was metallurgist for Erie Forge Co. of Erie, Pa., but then joined Weston-Mott Co. of Flint, Mich., which manufactured automobile axles. This firm was absorbed by Buick in 1917, and with the exception of about a year with Pittsburgh Crucible Steel Co. (1933-1934), he has been chief metallurgical engineer for Buick ever since.

Very early in this period he pioneered the use of pearlitic manganese steels, which were later applied to Buick axles, transmission and steering parts, and which have been used satisfactorily for nearly 30 years. In those days expensive alloy steels were used to offset poor heat treating practice (a habit which has not entirely vanished in American industry today). The medium-manganese steels undoubtedly needed more precise treatment than the nickel-chromium S.A.E. 3135 steels formerly used; therefore better furnaces and controls were needed. "R B" helped in the development of improved furnaces and annealing and hardening techniques.

In the early 1930's he recommended the purchase and supervised the use of the first continuous controlled atmosphere furnace to be installed by the automobile industry. This led to some of the early work in carbonitriding of automotive parts; the process has since become an important part of modern heat treating. Under SCHENCK's stimulation, Buick's staff has continuously been working with advanced furnaces and heat treating methods; "Buick practice" is almost synonymous with "best practice".

During the late 1930's he began an experimental test program on the boron steels. Their use in production began in certain parts for 1941-model cars. Here again, SCHENCK was among the pioneers. Boron steels are now being urged for general use as an answer to the present shortages of critical alloys.

When "R B" first came to Buick the metallurgical department consisted of nothing much more than a small chemical and physical test laboratory. It has expanded into a well-integrated group consisting of chemical and physical control laboratories, research laboratory, welding, metallographic, spectrographic, X-ray, foundry, and pyrometer control facilities, as well as a small but active group engaged in furnace design.

Buick Motor Division of General Motors Corp. was deeply immersed in war work in both world wars. Automobile production was converted to aircraft engine construction, making the Liberty motor in World War I, and Pratt & Whitney aircraft engine in World War II. These, together with manufacture of many other military items, required sound metallurgical decisions. During the last war ROBERT SCHENCK was a member of the Iron and Steel Committee of the Society of Automotive Engineers which aided in the development and promoted the use of the national emergency steels designed primarily to use the tramp alloy in scrap to best advantage. At this time he was also instrumental in the metallurgical development of the 75-mm. steel cartridge case (and its acceptance by the Army) when copper and its alloys were critical. His work at Buick in metallurgy during World War II won for him an Army-Navy certificate of appreciation.

SCHENCK's career has been outstanding not only within his own organization but also in the automotive metallurgical field as a whole. He served as chairman of the General Motors' Metallurgical Committee for 10 years, and its subcommittee on productive steel for 15 years. During the second World War he served as a member of the War Engineering Board, and supervised four National Research Council projects for the

development of low-alloy, boron treated steels for armor plate and armor piercing projectiles.

A long-time member of the American Society for Metals, he served for two terms on the committee for the revision of the ⊕ Metals Handbook. In 1948 he won the Society's Distinguished Service Award for meritorious contributions to progress in alloy steels, the citation reading "for devising inspection and production methods whereby manganese steels could be widely used for automotive parts". He is also a member of the Engineering Society of Detroit, British Iron and Steel Institute, Society of Automotive Engineers, American Foundrymen's Society, American Ordnance Association, and the American Association for the Advancement of Science.

It would be interesting to reprint his own words about the origin of the medium-manganese steels, now standardized as the 1300 series.

"While working as a foreman in the armor plate department at Homestead in 1914, I ran across a sample of 0.35 carbon, 1.50 manganese steel which showed remarkably good tensile properties in the heat treated condition. These results indicated that manganese might be used in place of chromium or nickel.

"Further work was greatly hampered by difficulty in obtaining additional samples from other heats to verify the first results. Anything in the range of 0.20 to 0.50 carbon and 1.25 to 2.00 manganese was almost nonexistent. Laboratory melting furnaces were not readily available at that time for making experimental lots and, if they had been, most of us would have hesitated to predict openhearth properties from laboratory melts. About the only material to be found was occasional scrap from some heat that had been rejected because of its high manganese content.

"Another obstacle in the development work was the general skepticism encountered, the prevalent attitude being that if manganese was any good as an alloying element in the pearlitic steels, this fact would have been discovered long before."

It is likely that this mental attitude in "old-timers" has been encountered (with exasperation) by every vigorous young engineer since engineering was an occupation. Suffice it to say that Bob Schenck has the very antithesis of a complaisant mind. No better example is needed than his reply to a newspaper reporter who came to interview him and to write a story about his impending retirement. Asked what he considered the outstanding development in metallurgy during his lifetime, Schenck cited something that occurred but yesterday:

"The splitting of the atom. I mean, the controlled fission of the heavy metals, rather than the atomic bomb. It foreshadows profound changes in metallurgy, in power development, and in our way of life." ⊕

Correspondence

Gradient Methods in Research

Paris, France

Phenomena involving many variables are frequently studied by holding all the variables but one as constant as possible and observing changes as the remaining variable is changed. This can lead to an overwhelming number of experiments. To reduce this work one can use — especially in the preliminary stages of an investigation — a "gradient method" which consists in replacing the discontinuous series of changes in the variable made at different times, with a continuous variation of the variable in a single sample.

Some examples are well known. There were Metcalf's classic experiments in which a comparative gradient was maintained to study grain growth, and Robin's experiments in which a temperature or a strain gradient was used to determine annealing conditions. Cooling rate gradients are used in studying hardenability (Jominy test) and velocity gradients are used in machinability tests. Fremont proposed the use of a truncated pyramid (which, on loading, gave a stress gradient) to determine the elastic limit in compression. Tensile specimens of similar shape could be used in studying stress corrosion cracking. Sauveur twisted rods that were heated to different temperatures along their lengths to illustrate the ranges of plasticity and their relationship with the transformations in steel. Tatur casts a star with arms of different length to test for susceptibility of aluminum alloys to cracking.

One can think of many new applications of the gradient method. For example, rods or tubes could be wrapped around a cone giving a

gradient in radius of curvature to test workability. Temperature gradients could be used in studying tempering. Balls of graded sizes could be pressed simultaneously into a sheet to test its drawability. Case hardened steels give a carbon gradient that is useful in many tests; sectioned specimens submerged in molten salt can be used to determine the equilibrium carbon content of the steel in that salt. Such specimens can also be used to study effects of various heat treatments, in combination with the Jominy bar (which in itself is an application of the gradient method).

We have used the method ourselves. In a preliminary study, Delbart and the writer heated a steel rod with a linear temperature gradient to study oxidation rates, carburization rates and nitriding rates.

Two variables can be studied at once by setting up gradients at right angles. For example, H. Granjon and the writer are studying the effects of temperature and quenching rates on hardenability and on the formation of Widmanstätten structure by this method. Another possibility of this two-variable method would be an investigation of the effects of cold work and temperature on annealing: A strain gradient and a temperature gradient would be set up in a sheet of metal, hardness measurements taken over its surface, which are then correlated directly with the amount of work and the temperature. Precipitation phenomena or Liesegang rings can also be studied by setting up diffusion gradients of two salts in gelatine plates and then putting the two plates together so that the gradient in each plate runs 90° to the other.

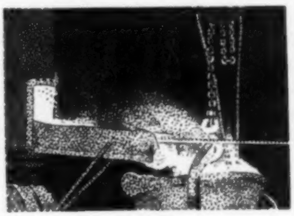
ALBERT PORTEVIN

Electrolytic Polishing of Nickel

PARIS, FRANCE

In the November 1950 issue of *Metal Progress* Glen W. Wensch describes a solution for electrolytic polishing of nickel for micrographic examination.

Electrolytic polishing, of course, is not a new process. It may be of interest, indeed, to record that the commercial process of electropolishing (French patent No. 707,526 issued to the writer in 1929) resulted from a search for a nonmechanical method for polishing micrographic specimens of this very metal.



Mr. Wensch recommends orthophosphoric acid. The micrograph published by him is somewhat dappled, indicating some variations in level. In my experience a better solution is composed of one part perchloric acid and four parts acetic anhydride, used with current of 18 amperes per square decimeter. Such a solution will polish nickel, even metal containing nonsoluble inclusions, to a *perfectly* smooth surface when viewed at 500 diameters.

P. A. JACQUET
Ingenieur Contractuel des
Constructions et Armes Navales

Zirconium for Manganese in Cupola Iron

UNIVERSITY, ALA.

In the article "Saving Precious Alloys by Intelligent Use of Alternatives" in June *Metal Progress*, James T. MacKenzie stated (p. 822) that experiments at the University of Alabama to substitute zirconium for manganese in cast iron appeared to be successful, but the Editor intimated that the cost of this substitution would be prohibitive. Contrary to this, it has been found that zirconium can economically be substituted for manganese in gray cast iron. In addition, a cast iron is produced which is more machinable and has better physical properties.

Zirconium-ferrosilicon (13 to 15% zirconium) is about the cheapest ferro-alloy available today. Briquettes can be made from this material which would contain 1.0 lb. of silicon and 0.3 lb. of zirconium in each 2.5-lb. briquette. These briquettes would sell for about 8¢ per lb. By using them in the cupola charge, it is possible to save approximately 40¢ per ton of cast iron produced. This saving is the difference between the cost of silicon and manganese briquettes used in conventional practice and the zirconium briquettes used on a substitutional basis. A typical cost comparison is shown in the table on p. 66.

Although it is more efficient and economical to add zirconium-ferrosilicon to the cast iron as a ladle addition, the use of zirconium briquettes would be preferred by the average foundryman.

This process of substituting zirconium for manganese has been checked in production foundries and found to be successful. Indications are that a better cast iron is produced at a lower cost by utilizing this method.

The writer is aware that

Comparative Costs, Mn Versus Zr

	Conventional Practice (Si and Mn Briquettes)	Suggested Practice (Zr-Si-Fe Briquettes)
Base Iron		
Pig iron	1500 lb.	1500 lb.
Steel scrap	500 lb.	500 lb.
Total	2000 lb.	2000 lb.
Alloys		
Si briquettes	75 lb. @ 7.1¢ = \$5.325	
Mn briquettes	10 lb. @ 11¢ = 1.100	
Zr briquettes		75 lb. @ 8¢ = \$6.00
Alloy cost per ton base iron:	\$6.425	\$6.00
		Savings per ton \$0.425
Final analysis		
Total carbon	3.36%	3.36%
Silicon	2.41	2.41
Sulphur	0.08	0.08
Phosphorus	0.27	0.27
Manganese	0.60	0.28
Zirconium	—	0.08

substitution of zirconium for manganese will not completely solve the manganese problem, but it is felt that it will help materially to relieve the cast iron foundryman from his complete dependence on manganese.

WARREN C. JEFFERY
Foundry Instructor
Department of Metallurgical Engineering

Modern Foundry Practice

LONDON, ONTARIO

In a recent visit to Chicago the opportunity was given, by kind American friends, to inspect some of the many brass and bronze foundries operating in that area. It was a welcome chance to view the latest in those processes that contribute to high quality, fast production, and low costs. Judging from the Editor's comments in "Critical Points" in the May issue, such matters are getting some intensive scrutiny in the United States at the present time.

Putting the various visits together the following impressions were gained:

In the old days when one visited a foundry he donned an old suit of clothes and prepared for dirty work. Not so today. No place is improvement more evident than in the main casting and molding floor. Line after line of molds move into position by conveyer and buggy. Pouring is done by one man (in place of three in the old days); he uses a suitable holding and tilting device for the ladle which has a connection on one side that keeps it in position at all times. A graphite skimmer acts automatically to screen any oxide or dross out of the pouring stream.

Melting is done in high-frequency stationary furnaces, or those of lift-coil type. Low-frequency furnaces may be used where production is of the same composition from day to day. Indirect arc electric furnaces (revolving drums) were also observed, but the foundrymen are not content to charge these furnaces at their rated capacity and then empty them — too much time is lost in the cycle. To reduce nonproductive period, furnaces of 750-lb. rated capacity are filled with 1500 lb. of metal and ladles of 250 lb. each are removed and 250 lb. of new metal added to the bath. Thus 250 lb. of molten metal is constantly available for pouring.

In the start of the molding operation the molder stands in front of his machine and an automatic buggy comes up beside him and delivers the flask. This does away with the back-breaking stoop.

In the fettling department and cleaning operations (and in fact in the plants generally) employees are encouraged to make suggestions that may reduce labor effort or otherwise speed up production. An instance was drawn to the visitor's attention where a simple chute was put in the rear of a cut-off machine so that the castings had only to be pushed away from the table. This got the man who made the suggestion \$700. Other labor-saving devices were seen here and there.

The old method of sandblasting, which was succeeded by steel shotblasting, is now tending toward the use of copper shot. This method gives a brighter finish, truer to the color of the alloy. Apparently the surface is more immune to grease marks from the hands of those who finally pack the finished castings. The comparison of the three methods is: Sandblast, dull and light colored, marks easily; steel shotblast, brighter and of a light color; copper shot, still brighter than steel, copper color on finished work which does not mark easily.

The aim of most of these foundries is a conveyer system to serve entirely automatic molding. When this idea has been completely developed, the workman will slide the flask (delivered to his machine by an automatic buggy) on the molding machine, open the slide

of the sand chute, press a button. From then on the squeezing, jolting, and conveying of the flask to the casting floor will be automatic. The drag and cope go to a transfer point where the mold is closed mechanically. If cores are required they will be set in by hand. Production in this manner is estimated to be about 15 sec. per mold (flask size, 12 x 18 in.). It is along these lines that production will be speeded up so that more metallic articles can be produced per hour in a given floor space and by a given staff.

HAROLD J. ROAST
Bronze Foundry Consultant

Palladium Alloys

LONDON, ENGLAND

The British professional body, the Institution of Metallurgists, recently held an exhibition in London to feature "Metals in the Service of Mankind". At the opening ceremony, a metal rose bowl was presented to H.R.H. Princess Margaret. Its appearance caused some conjecture as to what metal had been used to make it look so attractive. It was actually made of palladium hardened with rhodium.

Palladium is naturally a ductile white metal which retains its color and appearance in the atmosphere at ordinary temperatures. It is very resistant to chemical reagents, although it dissolves in aqua regia. The pure metal is too soft for jewelry and similar applications, but it may be satisfactorily hardened (without losing too much of its cold working properties) by such metals as ruthenium, rhodium and tungsten, the former exciting most commercial interest. The specific gravity of palladium is 11.96, the alloy hardened with rhodium is 12.03 — thus being considerably lighter than platinum or gold. Palladium possesses approximately the same hardness as platinum and work hardens in a similar fashion. The Vickers diamond penetration hardness number increases from 44 as annealed to 88 after a 25% reduction by cold rolling, and to 106 after a 50% reduction. The tensile strength of the annealed metal is about 30,000 psi.

Rhodium is also one of the rarer metals of the platinum group. It has a pleasing white color, has a density of 12.44 — only slightly greater than palladium — and is rather difficult to fabricate.

Both metals, of purity greater than 99.9%, were furnished by the Acton refinery of Mond Nickel Co. Baker Platinum, Ltd., fabricated it.

A high-frequency furnace is used to melt palladium (its melting point is about 2830° F.). After adding any required hardener to the melt, a suitable deoxidizer such as aluminum or calcium boride is added before casting. The ingot is usually broken down hot, and the sheet or other shape finished by cold working.

Rose Bowl of Palladium

A blue and red film of oxide can develop at about 750° F., but this decomposes at 1470°. Such a temperature, however, used in an attempt to remove the oxide from a finished product, may cause distortion, so the oxide is often chemically reduced to metal by immersion in warm formic acid. Quenching from the annealing temperature of about 1850° F. prevents the formation of "firecoat" (oxide). Palladium alloys may be joined by a number of special solders of suitable color, using borax as a flux.

Princess Margaret's bowl is $6\frac{5}{8}$ in. in diameter and weighs 709 g. The decorations were made by the precision casting process.

TOM BISHOP

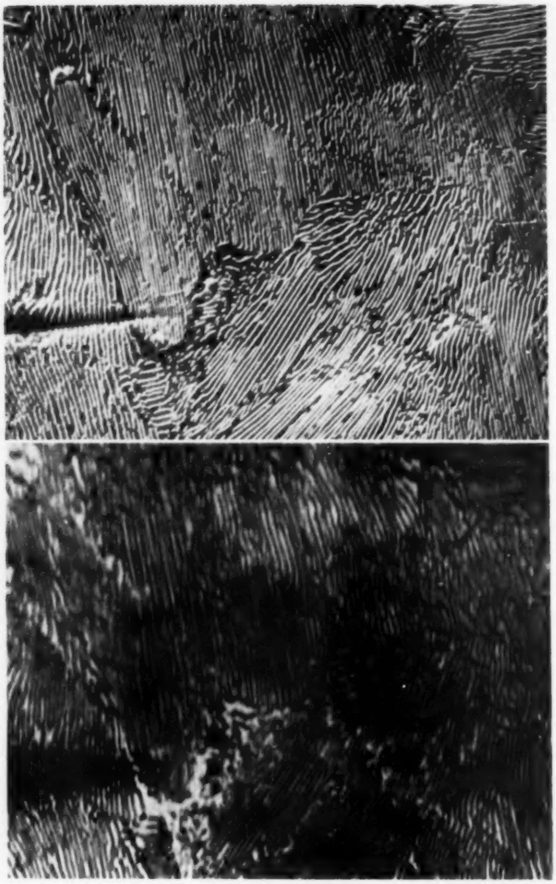


Fig. 1 — Photomicrographs of Same Area Showing Increase in Resolution of Microstructure in 0.90% Carbon Steel, by Use of Electron Microscope (Top) in Comparison With the Light Microscope (Bottom). Knoop hardness indent (lower left in micrographs) used as a reference. 2000 ×

Preparation for Electron

By William J. Craig
Research Associate

SINCE the introduction of the compound microscope, our knowledge of the microstructure of metals has developed tremendously. The microscope employing visible light for illumination, however, is somewhat limited in resolving ability by the wave length of the illumination and the numerical aperture of the lense system. A microscope with greater resolution would increase our range of vision in the study of those structural characteristics not visible with the metallurgical microscope. This has brought about the development within the last 20 years of the electron microscope. The name arises from the fact that electrons are utilized as a means of "illuminating" the object to be examined. In Fig. 1 the increase of power of resolution of electron micrograph is evident in comparison to the light micrograph of the same area.

Present design of the electron microscope is based on transmission of electrons through the object to be viewed. This leads to certain disadvantages for use in the examination of metal structures and necessitates development of specialized techniques of specimen preparation. It is the purpose of this paper to guide the metallographer in making such use of the electron microscope and acquaint him with a procedure that has been found satisfactory for making surface replicas of metallic specimens.

Since all material absorbs electrons, only very thin sections, either of the specimen or reproductions of the specimen surface, can be examined in the transmission-type microscope. Sufficiently thin sections of metal are very difficult to prepare for study of metal structures with the electron microscope; therefore, the technique of making plastic reproductions or "replicas" of the metal surface has been developed. These thin replicas, which are about 500A units in thickness, may be either negative or positive. Single or negative replicas (which represent "castings" utilizing the metal

Fig. 2 — Deformation Marks and Twins in Cartridge-Brass Tension Specimen Produced by Subjecting It to Maximum Load After Electropolishing. Negative parlodion replica shadow cast with chromium at an angle of 3 to 1. 6000 ×

# of Replicas Metallography

**University of Illinois
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surface as a mold) offer advantages for the study of fine detail. Sometimes the electron metallographer uses a double replica technique in which a second thin replica or positive is cast from the original replica. The negative replica is heavy and strong; hence, it can be stripped more readily from rough or deeply etched surfaces than parlodion. This process is tedious and laborious and is used only when the single negative replica cannot be successfully stripped. A greater amount of time is involved to make a positive, and some of the detail is lost through the double reproduction process.

In addition to plastic replicas, metal oxide coatings and cast metal films have also been used. There are disadvantages with each type. Metal oxide replicas are produced on either aluminum or stainless steel but the surface of the specimen is altered by the process required for removal of the oxide replica; these oxide films are extremely fragile and therefore hard to handle. With plastic replicas, one of the disadvantages is a minor toxic effect of the solvent in which the plastic is dissolved. This toxic effect is most evident to the metallographer at the time he applies moisture from his breath to the parlodion film.

The steps required to make plastic parlodion replicas of a metal surface can be enumerated in the following manner: (a) material surface preparation, (b) applying and drying the parlodion, (c) stripping the parlodion film, and (d) shadow casting and hardening the film. In making satisfactory replicas, the metal surface must meet several requirements. It must not be too rough, but at the same time it is only because of surface relief, which is reproduced by variations in thickness of the replica, that an image can be seen in the electron microscope. If the surface is too rough, the replicas will not readily strip off because of mechanical "keying" with the roughened surface.

In preparation of steel surfaces, the ordinary metallographic polishing procedures are used followed with a very light etching; such as required for magnifications above 1000 × with the light microscope. If the surface of the metal is overetched, it should be repolished and etched a lesser amount. Some etchants will produce staining which is not visible in the electron microscope. In studies of slip and processes of inelastic deformation, as shown in Fig. 2 and 3, an electrolytic polish gives a very smooth surface in which relief marks from straining are clearly evident. Electrolytic polishing also is advantageous in producing smooth surfaces on single-phase materials without

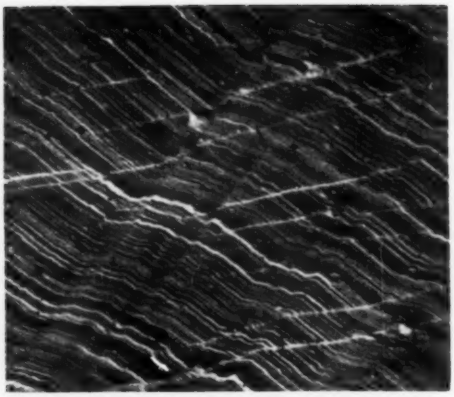


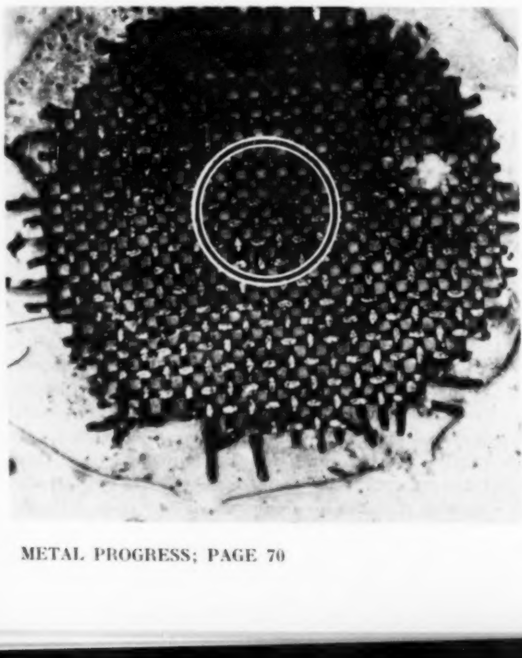
Fig. 3 — Deformation Marks Formed on Cartridge-Brass Tension Specimen. Negative parlodion replica, shadow cast with chromium at an angle of 3 to 1. (Black spots caused by foreign particles that deposited on surface when the replica was stripped.) 11,000 ×

cold-working or flowing of the surface of softer metals, such as brass and aluminum.

The plastic film is formed by flowing a solution of parlodion of proper concentration on the metal surface and allowing it to dry in a vertical position. This solution is made by dissolving chemically pure parlodion (prepared by Mallinckrodt) in 50% ether and 50% amyl acetate to give a 1% solution. This solution is then progressively diluted to approximately 0.5% until a straw-yellow to light-blue diffraction pattern is produced from reflected light when the solution is dried on a glass laboratory slide. The yellow to blue diffraction color is a measure of the concentration needed to produce proper thickness of parlodion film for use in the electron microscope.

Stripping the parlodion film is accomplished by use of moisture to break the bond, and a grid and scotch tape to support the thin parlodion film. The details of stripping are as follows: After the parlodion film is dry, a 200-mesh stainless steel screen grid (see Fig. 4) is placed over the desired area. Moisture is supplied by breathing on the film several times to break the bond with the metal surface. The scotch tape is pressed as quickly as possible against the area moistened by the breath, and then lifted. This is a very important step leading to successful stripping of a replica. It is thought that moisture condenses on the cold metal surfaces after diffusing through the parlodion film. This detaches the film from the metal surface and the floated film with supporting grid is then lifted from the metal surface by the use of scotch tape. After successfully stripping the grid, it is detached by tweezers from the scotch tape and placed on a glass slide in preparation for shadow casting. In many instances it will be possible to strip several grids with films at one time.

Fig. 4 — Macrograph of 200-Mesh Grid With Cellophane Tape on Top Side and Parlodion Film Below; Junction of Tape and Parlodion Film Is Visible as a Line Around the Grid. Circle enclosed area examined in electron microscope. 30 ×



Since the parlodion replicas generally do not have enough thickness variation to produce images of good contrast, shadow casting is employed to increase the differential transmission or absorption of electrons by the replica. Shadow casting is done in an evacuated chamber (10^{-6} mm. pressure of mercury or less) by evaporating a thin layer of some heavy high-melting point metal or alloy onto the parlodion film which is supported by the screen grid.

One reason for the high vacuum is to insure straight line paths of evaporating metal ions. If the paths are not straight, due to collisions with air molecules in the evacuated chamber, the shadows produced are not sharp; this induces some limit on the resolution obtainable. The metals or alloys used in shadow casting are chromium, palladium, platinum, gold, uranium and alloys of palladium and platinum. Since heavy metals such as these absorb electrons or offer greater resistance to their flow, they are deposited on the replica to enhance the contrast.

The metal is evaporated from a heated filament and is projected at an angle about 30° with the surface of the replica. The filament is made of 20 mil. (0.020 in. diameter) tungsten wire in the shape of a conical basket. The shape is produced by winding the wire around a small wood screw to form the basket; when removed it forms a container for the metal to be evaporated.

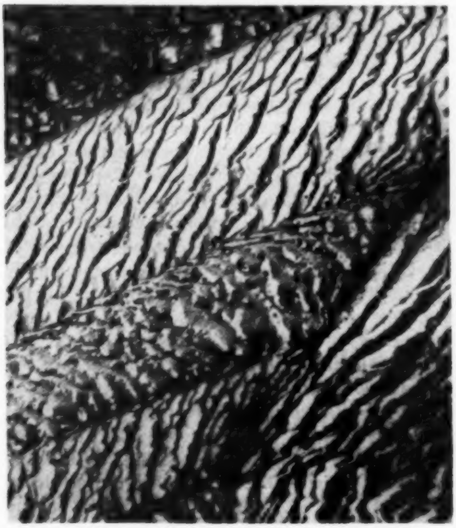


Fig. 5 — Area of Cartridge-Brass Tension Specimen Similar to That Shown in Fig. 2, Except That the Surface Was Electro-Etched Prior to Plastic Deformation. Negative parlodion replica shadow cast with chromium at an angle of 3 to 1. 6000 ×

The amount of metal, such as chromium or palladium, that is loaded into the basket depends on distance from filament to parlodion replica. If the distance from filament to replica is about 3 in., the amount of palladium to be loaded in the filament basket is about $\frac{1}{16}$ in. length of No. 20 gage wire. The metals have high rates of evaporation at or slightly above the melting temperature at the very low pressures used in shadow casting. The temperature of the filament, which is controlled by a Variac (continuous variable transformer), should be progressively increased until the metal in the basket melts and evaporates. The metal ions travel in straight paths to the surface of the replica which is thus coated with metal, except where a surface irregularity intercepts the beam of ions and shields a small area thereby leaving a metal-free shadow. The metal which would have covered the region of the shadow piles up on the exposed or raised face of the surface irregularity and forms a relatively dense deposit.

In the electron microscope, the areas of shadow transmit electrons and thus are bright, whereas the areas built up with metal absorb electrons and are dark. The height of surface irregularities on the replica may be estimated by the length of the shadow and the angle of incidence used in shadow casting. Thus shadow casting serves two purposes: (a) To increase contrast and (b) to aid in the estimation of the approximate height of surface irregularities on the replica.

Processing time required to shadow cast depends primarily on the time required to evacuate the chamber; generally, about 30 to 45 min. Time required to evaporate the metal is only a few minutes.

After shadow casting, the parlodion replica (attached to the grid) is ready to be hardened chemically before being put into the microscope. The hardening process is essential to prevent the film from being split and destroyed by an intense beam of electrons in the microscope. This hardness is achieved by dipping into carbon tetrachloride which promotes faster drying. After chemical hardening, the grid with parlodion replica is placed into a special removable holder in the electron microscope. The film may also be hardened in the microscope itself by slowly and carefully heating the film by controlling the intensity of the electron beam. The electron micrographs contained in this report were enlarged from 2 x 2-in. lantern slide negatives made in the RCA Electron Microscope, Type EMC.

When all factors such as wave length of illumination, numerical apertures and faithfulness of reproduction of parlodion replica are considered, the electron microscope extends our limit of resolution to about 100A units. The resolving power of the light microscope using blue light is about 2000A; when white light is used, the resolution is about 4000A. Hence, there is a 20 to 40-fold improvement of electron over light metallography. With this gain in resolution and the ease of preparation of parlodion replicas from metal surfaces, the metallographer has a valuable tool to extend our knowledge of structure and structural behavior of metals.

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A Suspended Graphite-Spiral Furnace

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THE FIELD of high-temperature metallurgy is well served by recording any advantageous modifications of high-temperature generating equipment. A graphite-spiral furnace, designed and put to use in the Polytechnic Institute of Brooklyn metallurgical laboratory, merits a brief description as it might be adopted elsewhere either for research or production purposes.

The furnace differs from the conventional graphite-spiral type in that it has only one rigid mechanical connection of the heating coil; the second rigid joint being eliminated by having the end portion of the graphite spiral suspended in powdered graphite. This innovation insures adequate electrical contact and eliminates the precision machining heretofore necessary for good alignment and fitting of the component parts. Also, chances for breakage of the fragile spiral during assembly and furnace operation are considerably reduced.

Additional advantages provided by this design are the following:

1. Temperature ceiling above 4000° F.
2. Very fast heating rate.
3. Control of temperature at a level required by controlling the heating current input.
4. Enlarged uniform temperature zone.
5. Long life of the heating spiral.
6. Possibility of employing inert atmospheres.
7. Rigid construction.
8. Possibility of using it for hot-pressing.
9. Low labor and material costs.
10. Possibility of adjusting the resistance of the heating coil to the available power supply and control equipment such as welding generators and transformers.

These features make this furnace suitable for such uses as melting, calibration of optical pyrometers, heating for heat treating operations and for sintering and hot pressing. The advantages listed under 9 and 10 should make it particularly attractive to those requiring high temperatures but handicapped by lack of funds.

As may be seen in the accompanying illustration, the furnace is heated by element "A" which is made into a spiral out of a commercial graphite tubing. The spiral has a taper at one end for attaching it firmly to the cylindrical graphite block "B". This block rests on the top of the furnace body made of insulating material. The side of the cylinder "B" is tightly encircled with ¼ x 2-in. copper strip, one end of which extends horizontally and is screwed to the vertical bus bar "C". The bus bar is rigidly anchored to the top of the furnace table and ends with the cable-clamping terminal "D". This arrangement prevents any transfer of forces onto the spiral from the current supply cable. The second clamping terminal "D'" is for the same reason fixed to the soapstone top. It is connected to a ⅛-in. thick copper plate "E", which is slightly elevated above the furnace top by means of supporting copper bars "F". A thick graphite crucible "G" rests on this platform and provides the furnace cavity in which the heating spiral hangs. The heating current circuit is completed by a quantity of powdered graphite deposited on the bottom of the crucible. The lip of the crucible "G" is insulated from the graphite block "B" by a ring "H" which is of good quality refractory cement. The outer shell of the furnace provides thermal insulation as well as mechanical support. Two transite rings "I" and "J" form the top and an outer part of the bottom of the furnace proper.

These rings are separated by a cylindrical steel shell "K", and secured by means of tie rods. These are not shown in the figure. The space between the furnace wall and the graphite crucible carries two layers of insulation, one of refractory cement "L" and the other of powdered carbon "M".

For low-temperature work, the furnace is

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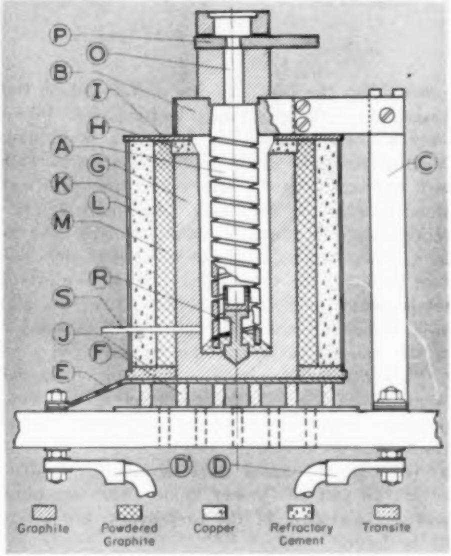

By Suspending the Furnace Element, Only One Rigid Mechanical Connection Is Needed; Electrical Contact at Free End Is Made in Powdered Graphite

A.	Spiral element	I.	Top transite ring
B.	Graphite block	J.	Bottom transite ring
C.	Bus bar	K.	Steel shell
D, D'.	Cable terminals	L.	Refractory insulator
E.	Copper plate platform	M.	Carbon insulator
F.	Copper support bars	O.	Furnace closure
G.	Graphite crucible	P.	Shutter
H.	Refractory ring	R.	Crucible pedestal
		S.	Gas delivery tube

closed with a stopper made of graphite. For high-temperature work, where radiation losses during opening of the furnace for inspection or temperature reading considerably affect the temperature level, a furnace closure "O" is used. It is made of two carbon rings which are held in alignment with the furnace opening by locating pins. The top ring has a recess for a silica window, and on the bottom side a slot for the sliding, shutter "P". The shutter is made from a rectangular piece of graphite with a round hole off-center. For inspection or temperature reading, this hole is brought into alignment with the axis of the furnace. At other times, the solid part of the shutter effectively closes the furnace. The bottom ring merely elevates the shutter above the furnace top for easier sliding.

The furnace, unlike its original version, develops the highest temperature not in the middle but near the bottom, the numerous arcs between graphite particles being responsible for this effect. The high rate of heat generation in this part of the furnace more than compensates for heat losses and thus is responsible for an increase in length of the uniform temperature zone. To take full advantage of this condition, it is only necessary to employ thick-bottom crucibles or a short elevating pedestal "R" to bring the charge into the uniform temperature zone. The fact that the pedestal is short and thus not subject to breakage by buckling, as well as the fact that it rests on a firm understructure, enables this furnace to be used for hot pressing work. It will be noticed that changing the distance between the end of the spiral and the bottom of the crucible or, alternatively, changing the grain size of the graphite powder, makes it possible to extend the uniform temperature zone almost to the very bottom of the spiral, this helps when large compressive forces are used or long objects are heated.

The high rate of heat flow through the bottom of the furnace, due to the "hot bottom" effect, calls for adequate cooling of the copper plate "E". Water cooling was contemplated but rejected as unduly complicating the furnace. Instead, straight convection cooling was adopted and found adequate. To enable the air to flow near the plate, the latter was elevated by copper bars "F" and a series of holes was drilled in the slate top for better ventilation.

Normally, the furnace cavity has a slightly carburizing atmosphere. When this is objectionable, an inert gas can be introduced into the furnace by means of the tube "S".

The heating spiral deserves a little more attention because it determines the furnace

Operating and Physical Data of Element

Power Supply:	10 Kw. d.c. generator, 250 amp. maximum, continuous voltage control between 0 and 40 volts.
Spiral Element:	2-In. i.d. graphite tubing, $\frac{3}{16}$-in. wall thickness, over-all length $9\frac{1}{2}$ in., slotted length $7\frac{1}{2}$ in., 22 slots per ft. or $\frac{17}{32}$-in. distance between slots.
Performance:	Room temperature resistance across the furnace terminals 0.3 ohm. Maximum temperature reached 3550° F., maintained within ±25° F. for 2 hr. Power input at maximum temperature 6.1 kw. Lower temperatures readily maintained by voltage control. Total heating time to date above 2000° F., approximately 30 hr. Spiral after 30-hr. operation (without inert gas protection) shows no oxidation.

performance. A new furnace has to have a uniformly heated space the size of which is usually known. This space is first expressed in terms of inner diameter of standard graphite tubing and in tube length. The latter dimension is subsequently increased by about 50% to provide for the tapered connection and for portions that will exhibit temperature gradients. A commercially available wall thickness is then selected.

Spirals with different electrical resistance can be obtained from such a tubing by employing different slotting pitch, different slotting width, or by reducing the original wall thickness.

When the power supply on hand has a limited range of voltage and current, a heating spiral with optimum resistance is needed to permit maximum power input. The latter, it will be remembered, together with the furnace insulation, governs the temperature ceiling of the furnace. The matching of the spiral to the power source is done in the following manner:

A length of tube is first tapered on one end, cut to exact length and then slotted in a miter box. A thick hacksaw blade guided by a slot suitably inclined to the miter box axis is all that is needed for this task. A spiral thus made is fitted to the furnace and tried. If it draws more power than the rating of the power source, the resistance of the spiral must be increased. When only a small increase in resistance is needed, heating the spiral in air may be resorted to; this will oxidize the spiral, decrease its thickness and thus increase the resistance. To obtain a large increase of resistance, a new spiral will have to be made employing a greater number of slots per foot. Should the first spiral develop too low a temperature and take less power than is available, either a lower-resistance spiral is needed or the thermal insulation must be improved.

The fitting of the furnace to the power source is completed when the furnace develops the temperature ceiling demanded. Any temperature lower than the maximum can then be maintained by reducing the power either by voltage control or by "on and off" power input. The operating and physical data of the installation are given in the table.

Altogether the furnace behaved satisfactorily. However, more economical operation, as well as a higher temperature ceiling, would be possible with a better thermal insulation and by enlarging the cross sections of copper parts. Because the graphite closure oxidizes excessively, in the future it will be of refractory material.

Welding Fractures

By E. P. DeGarmo
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University of California
Berkeley

Contrary to what seems to be the practice of some people in welding, I am going to state very flatly that we do get failures. Furthermore, I think we will continue to get them until we give a little more thought to what causes them and make use of some of the information which has been developed in the last several years. I don't believe there is very much reason any more to have welding failures. We don't know the whole story, but I think we do know enough to prevent most failures. Now let's pause a few moments to see what we do know.

First of all, welding failures are not restricted to large structures such as ships or bridges. They occur on structures of very much smaller size. I have seen so-called "brittle" failures occur in structures where the main member was no more than $\frac{3}{4}$ x 2 in., so we have to recognize that there may be some dangers in structures of most any size unless we follow certain precautions.

Now what is it that causes the welding failure? The causes can be classified under three heads. First, and I put this one first because I believe it is probably the most important, is that of improper design. I am not going to say too much about improper design because this is a session on metals. I am going to say a little bit more about the metals, which I would classify as the second most important factor and one about which we can do quite a bit. Specifically, this pertains to poor steel, or steel which is not of the proper quality to give good service in welded structures under service conditions. Then we have the third factor, poor welding practice. We are not going to say too much about this except

to point out this factor. Here again a great deal can be done by design.

It must be remembered that any one of these factors might cause a failure, although in most instances we invariably find two or more of them are present when we have a serious welding failure. Very frequently we are confronted with the problem of whether the egg or the chicken came first, but on the other hand, we have often committed some atrocious crimes in connection with design used for welding. It has been said for a good many years that we can't just take riveted design and weld it, and certainly we have learned this in connection with welding failures.

What is it that we must remember? First of all, very frequently we are dealing in welded design with a one-piece or monolithic structure and this creates some inherent hazards. If a fracture does start in such a weldment it is very apt to go throughout the structure and cause complete failure. That is not the case when we are dealing with certain other types of construction. However, this is not a serious problem; it is simply one that we have to recognize and take into account. Second, we have to remember that it is very easy, much easier with welding than with riveting, to introduce notches into a structure and I think we have to be certain that we take a broad definition of this term notch as being any severe change in the cross section. It is so simple with welding to join a couple of pieces so as to create a notch. It is also possible to do it, of course, through poor procedure. What we have to remember is that much can be accomplished through proper design.

I would like to say a few words relative to welding technique. One important point is — be careful of what may appear to be insignificant in your welding practice. Little simple things like striking an arc may not be given much consideration — yet more than one failure has been traced to the point where a welder struck an arc. This is an insignificant thing; you can barely see it on the plate. But we may have to revise some of our thinking about welders just striking the arc anywhere and starting off making a weld. We may have to provide proper procedures for letting them strike the arc down in the groove where they will go over it again. Attaching miscellaneous clips and brackets may also cause trouble if done indiscriminately.

We have such things as preheat and postheat treatments to consider. All the tests I have made to date indicate that you get just about the same advantage from the standpoint of weld performance by using 400° F. preheat as you get by using 1100 or 1200° F. postwelding heat treatment. Yet, many of our codes specify that we must postheat and will not allow us to substitute preheat. I have been unable to find proof that, as far as weld performance is concerned, postheat is any better than preheat treatment. There are a few exceptions, but I am talking about the ordinary structural steels. We need to learn more about these things and understand what has been done. Preheat has been an extremely effective practice; some of its metallurgical results are rather astonishing. We need to recognize that ordinary, so-called low-carbon steels of the type that have been normally welded can be damaged metallurgically in the welding process. It's not just when we get up to the high carbon steels that trouble may be encountered. Some of these procedures, problems and techniques we will need to get acquainted with if we are going to weld structures that have to be subjected to low-temperature conditions.

The American Welding Society specification for welding a relatively thin plate to a heavy member stipulates that such weldments be furnace stress-relieved. A procedure we can use under conditions where there are inadequate facilities for this treatment is to use preheat. Properly used, it is about as beneficial as postwelding heat treatment. If one would, in this case, preheat both the heavy and thin sections, and see to it that the thin section is kept heated so that it won't cool too rapidly, I am quite convinced one could get all the benefits that would be obtained from the other treatment. This could be done with an ordinary heating torch, or with a scaling torch — it works beautifully.

It would be advisable to specify an allowable rate of cooling for the thin member, and this doesn't have to be a very slow rate. If the thin member is kept up to about 200 or 300° F. until the welding is completed and then just a little heat retained on it so that instead of cooling in a few minutes it cools in 10 or 15 min., there will be little chance of any trouble.

Most of us have heard a great deal about how many Liberty ships failed, but I suspect very few of us have heard anything about how many Victory ships didn't fail. That not one Victory ship has had a major failure can be, I think, attributed primarily to changes in design. Incidentally, they were designed very well from the welding standpoint, although I wouldn't say that the ultimate in design was used in all respects. This is largely because the policy adopted was somewhat like that assumed by a patient who, when told by a doctor to take one pill, figured if one was good, 10 would be better,

so the designers used more metal than I think there was any necessity for. But the fact remains that there haven't been any Victory ship failures.

It is interesting to note from the record of the service failures in ships that where the design was poor, the percentage of failures was high. For example, if one considers the original Liberty ships, which had some very poor design features, one has a figure of 19.45 (a relative figure). For an all-welded Liberty ship, but with some improved design details, the figure is down to 3.56; cut roughly to 1/6 of what it was before through improvement in design. As another example, it has been demonstrated that a certain type of structure using a poor design will fail at about a million and a half pounds load but by designing it properly — and actually using less metal — it will withstand a load of 3¼ million pounds. I think those figures ought to be enough to call attention to the importance of good design in eliminating a lot of difficulties.

REQUIREMENTS OF WELDABLE STEELS

Now, when we start talking about design, we have to remember that steel welded into large structures behaves quite differently than in a small test specimen. This brings up the factor of steel quality. The thing we have got to deal with is the question of transition temperature. Figure 1 shows what happens when Charpy

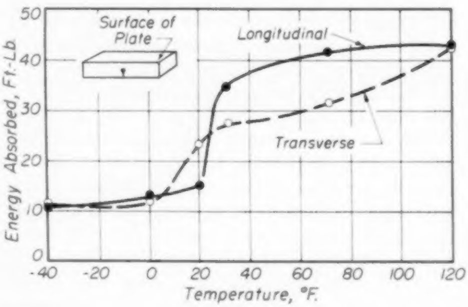


Fig. 1 — Transition Curves for Small Test Specimen of Steel Obtained With Charpy Keyhole Notch Test

V-notch tests on a given steel are made at various temperatures. Most any steel tested in this manner will reveal that, in the presence of a notch, the energy required to fracture it at elevated temperatures is rather high, but as the temperature is lowered and the tests continued, the energy drops off very sharply. Unfortunately, the ordinary tests that we have had until recently did not give us a true indication of the temperature at which the steel might cease to behave in a manner in which it would absorb high energy and start behaving in a manner where it absorbed very little energy, or change from a ductile fracture to a brittle-type fracture.

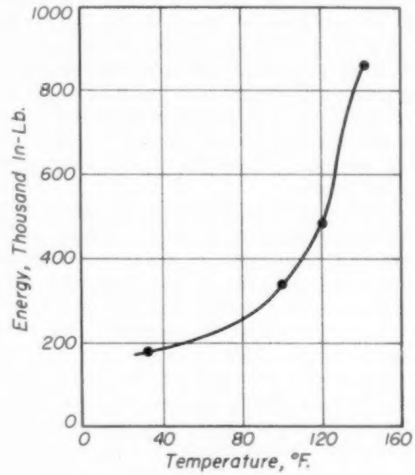


Fig. 2 — Transition Curve for the Steel of Fig. 1 but Welded Into Large Structure

Therefore, we must recognize in our design that we need some more information about our steels. For example, Fig. 2 shows a transition curve for the same steel as used in Fig. 1 *but when welded into a large, rigid structure.* Note that there is about 85° F. difference in transformation temperature. We have learned a lot about steels in the last few years, but we still don't know all we want to know.

Let's consider some of the effects of the various constituents that we find in steel. For example, it has been found that increasing the carbon about 0.10% will increase the temperature at which steel fails in a brittle manner by about 40° F.; so we emphasize again the necessity for keeping the carbon content low if we are going to use a welded structure for low temperatures. It has been demonstrated that grain size is very important. This can be very well controlled, as you know, by the finishing temperature at which we finish the rolling. Changing the finishing temperature from about 1650 to 1850° F. increases the transition temperature about 45° F., which means that you may have a steel at ordinary service temperatures which may very easily fail in a brittle manner.

The vanadium content is very critical. If

vanadium is increased by about 0.10%, the transition temperature is increased about 70° F. Manganese, on the other hand, lowers the transition temperature very markedly; so, if we increase the manganese from about 0.4 to 0.8% it will decrease the transition temperature by about 15 to 20° F. The point is, that if we are going to use steels in welded structures which have to operate at reasonably low temperatures, and this means climatic conditions in most of this country during the winter, we have to be a little bit careful what we specify for our steels. Unfortunately, most of our specifications are not good enough; they just do not give us the steel that will be adequate at these temperatures. We may need better specifications. One of the first steps in this direction has been made by the American Bureau of Shipping with a new specification for a steel that will be quite satisfactory for service conditions which are apt to be encountered by ships. I think we are going to have other specifications rewritten if we are going to use steels in welded structures that have to be subjected to low temperatures, particularly in large structures.

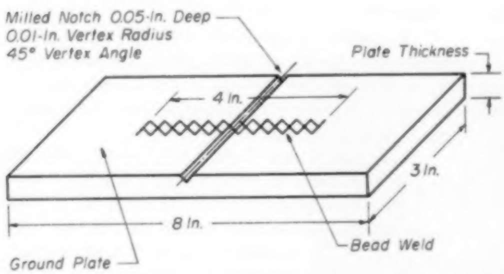


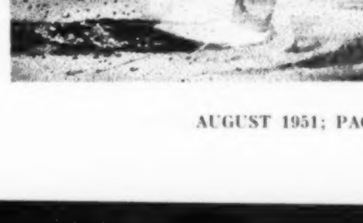
Fig. 3 — Kinzel Bend Test Specimen Indicates Behavior of Steel When Welded and Its Transition Temperature

The problem is how to write such a specification, or probably more important to you, how to test the steel to find out whether it's going to be adequate. I pointed out that the Charpy bar test does not give a very good indication. There have been several tests devised and probably one of the best is the Kinzel bend test. Figure 3 shows the essentials of the Kinzel test. It will indicate the way a steel will perform when welded and will tell the temperature at which the transition will take place. As a rule, the actual transition temperature in the welded structure may be from 10 to 20° higher than the Kinzel test specimens show, but at least it is a much better indication than the Charpy bar.

I don't feel very optimistic regarding the possibility of converting a transition temperature as determined by a Charpy impact test to the transition temperature as determined by the Kinzel bend test, or other types of tests for evaluating transition temperatures. It has been found that while any of the notch tests will classify the steels in their relative order with fair accuracy, they do not have the kind of relationship that will permit the use of a conversion factor to get an accurate transition temperature in an actual structure. Then there is a further problem; the Charpy test tells only about the steel, but not about how the steel behaves when welded because there is no weld in it. The Kinzel test, and one or two others, involve a weld bead for the notch and that, I think, is absolutely essential. Welds must be in the metal if one is to tell how it is going to behave in a welded structure.

Another thing we need to know more about is the effect of hydrogen. There is still much we do not know about this and there are several indications that it may play an important part in many "brittle" failures.

I think we must get acquainted with some of these problems so that, if we are going to use steels in welded structures, or supply steels for use in welded structures, we will be able to have one which will meet service conditions. It may increase the cost of our steel, but it's only going to be a very small amount. However, we will be able to use welded structures that will serve under all conditions, and because of the inherent savings made through the welding process and in the amount of steel needed, the total cost will be considerably less than if we were to use some other type of construction. The inherent advantages of welding are so evident and time-proved that it is folly for the engineer to fail to learn the requirements that go along with its proper utilization. Most welding failures have not shown much wrong with welding, but they have demonstrated lack of knowledge and understanding on the part of some who use it.



Current Russian Metallurgical Texts

By Carl A. Zapffe
Consulting Metallurgist
Baltimore, Md.

Socialistic organization of industry and labor began to be formulated at the moment of the accomplishment of the Great October Socialistic Revolution, when the proletariat of Soviet countries, under leadership of the Bolshevik party, took into their own hands the management of industry. "For the first time, after centuries of toiling under harsh and involuntary bondage to exploiters, there arose the opportunity of service for self, and moreover service which depended upon everyone for the winning of the newest science and culture."

Thus begins a 1950 Russian text, written for purposes of explaining the methods of Communism applied to the ferrous metallurgical industry. The included quotation is taken from the writings of Lenin. The 488-page book, "*Technical Standardization in Ferrous Metallurgy*", by S. M. Levin, L. M. Lieberman, M. B. Kotok, and B. B. Gildinier on the staff of the Ukrainian Scientific Research Institute for Metals and published by the Soviet government, proceeds with extensive time-motion studies, organizational schemes, and formulas for determining normal output:

$$N = \frac{T - t_z - t_v - t_r - t_o}{t_w}$$

where T = Duration of shift, minutes
t_z = Time for preparing and concluding work
t_v = Time for subsidiary work
t_r = Time for regulated intermissions due to technical causes
t_o = Time for relaxation, specified by the work authorities
t_w = Time spent in fundamental operations on a single unit of produce

On the basis of these and similar economy formulas:

$$E = \frac{(a \cdot g) + (b \cdot d)}{g + d} - (e + j)\,\frac{(b \cdot e) + (v \cdot j)}{(e \cdot j)}$$

the salaries of Russian metallurgists are based!

In peace or in war, Americans from now on will have constantly before them Russian words, Russian works, and probably the Russians themselves; and the present increasing tendency of universities and colleges in this country to teach Russian and to list that language as a requisite for advanced science degrees is much to be encouraged. It is sheer alibi to bypass Russian technical literature because of its alleged inferiority. That country has a research program easily matching America's; its personnel includes many of prewar Germany's ablest minds; and the very core of the communist ideology is "Science is Power". Some mediocrity should be expected; that, similarly, forms the healthy trunk of our own tree of knowledge!

For the past several years the author has studied the Russian language because of this rapidly increasing desirability of reviewing firsthand its technical publications. In the past winter it became possible to study a number of their textbooks — principally postwar publications — directly or indirectly concerning metallurgical subjects. Some of these will be briefly reviewed to give our American metallurgists a cross section of the status and progress in that country.

Surprisingly extensive collections of Russian works are for sale by the following organizations in New York City, to whom acknowledgment is herewith made for their cooperation in supplying material for this review:

Four Continent Book Corp., 38 W. 58th St.
Rogers Book Service, 268 W. 23rd St.
Stechert-Hafner, Inc., 31 E. 10th St.

Russian scientific books are much less expensive than might be expected. None of those reviewed here cost me more than \$3.50, most of them being in the range of \$1.00 to \$3.00 — figures which suggest a governmental subsidy.

Fundamentals of Metallurgy

By H. K. Avetisian
Govt. Sci.-Tech. Pub.* (Moscow), 287 p. (1947)

Although unimpressive in typography and format, this text has a technical content that will rank it high on any international listing of books for college use. A strictly comparable English text is not known to this reviewer, the

*Editor's Note — The abbreviated name is Metallurgizdat; the full title is State Publishing House for Scientific and Technical Literature on Ferrous and Nonferrous Metallurgy. "Metallurgy" in Russian, as in German, primarily includes reduction and refining rather than re-shaping or fabrication.

principal distinction lying in the common bias of American writers toward process metallurgy and practical metallurgy.

Instead, Avetisian's book attacks the subject from all its foundations in the basic sciences, beginning with a treatment of ideal gases, proceeding with a good coverage of metallurgically important thermodynamic relationships, deriving the phase rule, describing binary, ternary, and quaternary constitutional diagrams, similarly introducing ionics and electrochemical theory, and then galloping across major interests in both ferrous and nonferrous fields, explaining them on the basis of the prior theoretical treatment. This latter section covers a comprehensive range: Construction and general principles of operation of ferrous and nonferrous furnaces, including the blast furnace; concentrating, drying and roasting of ore; dust collecting; hydrometallurgy, ferrous and nonferrous; distillation and sublimation; gaseous reduction — principally H_2 and CO processes for iron ore; slag and slag-metal theory, including the recent ionic theory.

He wastes no words in this terse and rather impressive text, a circumstance which enables it to exceed considerably in scope what one would expect from a "fundamentals" opus. The attack is outstandingly Continental in its exact and mathematical bias. No references appear in the text, and many of the diagrams are more or less familiar as redrawn Occidental material. In an appendix there is a list of 27 references, most of them Russian, but it includes Schenck on steelmaking. No halftones appear, a photomicrograph of an ore sample being converted to a line drawing.

Numerous items in this book attract one's attention. First, the thermodynamic treatment of oxygen pressures of numerous metallic oxides is good, and a similar concern with sulphides is more extensive than usual. In fact, some of this latter suggests a considerably advanced treatment of copper-base alloys, particularly copper-nickel, on which attention has recently been keen in both England and America.

Second, the iron-carbon diagram is intriguing because of *(a)* a "reversed S" curve for the austenite-ledeburite boundary [ours is straight]; *(b)* a strongly downward-concave curve for the austenite-solidus boundary [ours is convex]; *(c)* a slightly upward-convex curve for a_3 [ours is slightly concave]; and *(d)* a designation of 700° C. for a_1 [ours is 723°].

Third, hydrometallurgy is given much attention, apparently in keeping with the trend of the industry in Russia. Avetisian names hydrometallurgy and pyrometallurgy as the two generalized systems of process metallurgy, and in a tabulation shows that zinc, particularly, is produced in Russia by electrolytic means.

Lastly, among minor points, there is an equation which, if conventional, has escaped this reviewer's education. It expresses the ionic self-reduction of iron:

$$2Fe^{\cdots} + Fe = 3Fe^{\cdot\cdot}$$

Fundamentals of Metallurgy

By G. A. Kashchenko
Govt. Sci.-Tech. Pub.* (Moscow), 639 p. (1949)

In considerable contrast to an inferior text by A. A. Bochvar on "Metallurgy", a 400-page governmental issue apparently intended for nonmetallurgical engineers, Kashchenko uses much more space to cover less story, with a resulting methodical treatment which is educational on a metallurgical level. Typography is also good, this being one of the better technical books from the standpoint of appearance.


P. P. Anasov (1797-1851), Russia's Pioneer Metallographer. (Sketched from a halftone in Kashchenko's text)

Beginning with an excellent and a rather rare description of Russian metallurgical history, accompanied by good portraits of a number of leading personalities, Kashchenko states that Anasov in 1831 applied the microscope to metals to study both macrostructure and microstructure, thus antedating Sorby in England by 30 years. While this reminds us of "something we have heard before", it is not an idle claim, for this reviewer has found mention of this in extra-Russian literature, and there is no need to question that Anasov was an outstanding metallurgist of a century ago, and it will be good to add herewith his portrait to the American literature.

Better known outside Russia is Chernov

(usually transliterated as Tschernoff). Kashchenko claims that Chernov discovered the critical points of steel and constructed a constitutional diagram 20 years before Osmond in France, and 30 years before Roberts-Austen in England. This cry of "first" seems a little overdone in contemporary Russian literature, even though there is truth in this particular report. On the other hand, Carl Benedicks has documented the fact that J. F. Angerstein discovered the Ac critical point in 1778.

In his careful development of metallurgical theory, Kashchenko presents a schematic Fe-C diagram which is reproduced in Fig. 2 because of its novelty.

One of the Russian mysteries of principal interest to this reviewer concerns their practice on stainless and heat resisting steel. An exception is the book on Fe-Cr-Al alloys by Kornilov, to be mentioned later. Published articles rarely disclose details of analysis or processing, and no books seem yet available for translating (although the reverse is true — the Russians translate without so much as "by your leave" such texts as "The Book of Stainless Steels", published by the).

Kashchenko gives some information on these steels in the course of his methodical discussion. He recognizes three broad classifications — chromium grades, Cr-Ni grades, and substitute Cr-Ni grades. The following specific steels are named by him:

Mark	C	Cr	Ni	Other
25M	0.20	23/27	—	0.8/1.2 Si
X18H8*	0.14	17/20	8/10	0.4/0.6 Mo
X14H14B2	0.4/0.5	13/15	13/15	2.0/2.75 W

*H is Russian for N

The first two are direct analogs of A.I.S.I. Types 446 and 302, respectively. The third is a special austenitic grade for valves and high-temperature structural service, suggestive of the English "12-12". Compositions analogous to Types 420, 440-A and 430 are also mentioned — the latter being called "semiferritic".

Substitutional alloys are noted as follows:

C	Cr	Ni	Mn	N
0.3	12	—	16	—
0.3	12	4	8	—
—	18	5	—	0.15/0.20

In general, his description of these steels sounds well-informed, but some question arises when his discussion of sensitization focuses on carbon contents exceeding 0.10% and a temperature range of 500 to 700° C. (925 to 1300° F.) for such limits concern only the phenomenon in its coarsest manifestations.

Nevertheless, this is an excellent book.

Akimov on Corrosion

One of the finest of the international texts to be found on corrosion is *"Theory and Methods for Studying the Corrosion of Metals"*, by G. V. Akimov, published by the Academy of Sciences, U.S.S.R., in 1945. It is of superlative presentation and above-average typography. Although its 414 pages is not nearly the size of Uhlig's "Corrosion Handbook", Akimov's book contains many interesting things immediately stamping it as an original source and one which should be consulted by students of corrosion. The text is well illustrated (373 figures); and among numerous attractive tabulations is one giving 17 methods of corrosion testing.

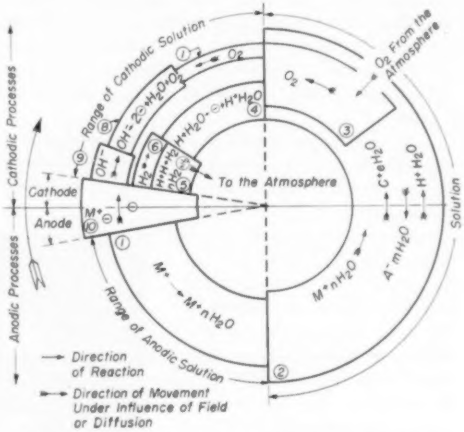


Chart Generalizing Corrosion Processes, According to Tomashev (Quoted by Akimov)

Akimov is particularly interested in "multielectrode" corrosion systems. [A "two-phase" stainless steel, such as an unbalanced Type 316, provides several corrosion electrodes: *(a)* austenite, *(b)* ferrite, and *(c)* carbide.] The cooling system for a motor provides five corrosion electrodes, brass radiator, cast iron manifolds, aluminum alloy pump, another aluminum cylinder head and a steel cylinder. He proceeds to discuss such systems both theoretically and experimentally, under the supposition that the electrodes discharge to a common center, each one discharges to its next neighbor, one receives the discharge of all others, and various combinations of the above. The chart shown above, generalizing the process of corrosion, is also good.

A second text by the same *(Cont. on p. 100)*

Boron and Alternate Steels

Lists Issued by American Iron and Steel Institute, June 13 and July, 1951

Grade	Carbon	Manganese	Nickel	Chromium	Molybdenum	Notes
14B35	0.33/0.40	0.70/1.00	—	—	—	2, 4
14B50	0.47/0.55	0.70/1.00	—	—	—	5
14B52	0.47/0.55	1.20/1.55	—	—	—	5
TS4012	0.09/0.14	0.75/1.00	—	—	0.15/0.25	1
40B37 Modified	0.34/0.42	0.70/1.00	—	—	0.08/0.15	2, 4
40B37 Aircraft	0.34/0.42	0.70/1.00	—	—	0.20/0.30	3, 4
TS4130	0.28/0.33	0.45/0.65	—	0.90/1.20	0.08/0.15	1
TS4132	0.30/0.35	0.45/0.65	—	0.90/1.20	0.08/0.15	1
TS4135	0.33/0.38	0.75/1.00	—	0.90/1.20	0.08/0.15	1
TS4137	0.35/0.40	0.75/1.00	—	0.90/1.20	0.08/0.15	1
TS4140	0.38/0.43	0.80/1.05	—	0.90/1.20	0.08/0.15	1
TS4142	0.40/0.45	0.80/1.05	—	0.90/1.20	0.08/0.15	1
TS4145	0.43/0.48	0.80/1.05	—	0.90/1.20	0.08/0.15	1
TS4147	0.45/0.50	0.80/1.05	—	0.90/1.20	0.08/0.15	1
TS4150	0.48/0.53	0.80/1.05	—	0.90/1.20	0.08/0.15	1
TS4720	0.17/0.22	0.50/0.70	0.90/1.20	0.35/0.55	0.15/0.25	1
50B15	0.12/0.18	0.70/1.00	—	0.35/0.60	—	5
50B20	0.17/0.23	0.70/1.00	—	0.35/0.60	—	5
50B30	0.27/0.34	0.70/1.00	—	0.35/0.60	—	5
50B35	0.32/0.39	0.70/1.00	—	0.35/0.60	—	5
5035	0.33/0.40	0.70/1.00	—	0.20/0.40	—	2
50B37	0.34/0.42	0.70/1.00	—	0.20/0.40	—	3, 4
50B40	0.37/0.45	0.70/1.00	—	0.35/0.60	—	5
50B44	0.42/0.50	0.70/1.00	—	0.35/0.60	—	5
TS50B46	0.43/0.50	0.75/1.00	—	0.20/0.35	—	5
50B49	0.47/0.55	0.70/1.00	—	0.20/0.40	—	5
50B50	0.47/0.55	0.70/1.00	—	0.35/0.60	—	5
50B60	0.55/0.65	0.70/1.00	—	0.35/0.60	—	5
80B15	0.12/0.18	0.60/0.90	0.20/0.40	0.15/0.35	0.08/0.15	5
80B17	0.14/0.20	0.60/0.90	0.20/0.40	0.15/0.35	0.08/0.15	5
80B20	0.17/0.23	0.60/0.90	0.20/0.40	0.15/0.35	0.08/0.15	5
80B25	0.21/0.28	0.60/0.90	0.20/0.40	0.15/0.35	0.08/0.15	5
80B30	0.27/0.34	0.55/0.80	0.20/0.40	0.15/0.35	0.08/0.15	5
80B35	0.32/0.39	0.65/0.95	0.20/0.40	0.15/0.35	0.08/0.15	5
8035	0.32/0.39	0.70/1.00	0.20/0.40	0.15/0.35	0.08/0.15	2
80B37	0.34/0.42	0.70/1.00	0.20/0.40	0.15/0.35	0.08/0.15	3, 4
80B40	0.37/0.45	0.70/1.00	0.20/0.40	0.15/0.35	0.08/0.15	5
80B45	0.42/0.50	0.70/1.00	0.20/0.40	0.15/0.35	0.08/0.15	5
80B50	0.47/0.55	0.70/1.00	0.20/0.40	0.25/0.50	0.08/0.15	5
80B55	0.50/0.60	0.70/1.00	0.20/0.40	0.30/0.55	0.08/0.15	5
80B60	0.55/0.65	0.70/1.00	0.20/0.40	0.30/0.55	0.08/0.15	5
TS8115	0.13/0.18	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8117	0.15/0.20	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8120	0.18/0.23	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8122	0.20/0.25	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8123 (S)	0.20/0.25	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1, 6
TS8125	0.23/0.28	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8126 (S)	0.23/0.28	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1, 6
TS8127	0.25/0.30	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8128 (S)	0.25/0.30	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1, 6
TS8130	0.28/0.33	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8132	0.30/0.35	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8135	0.33/0.38	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1, 2
81B35	0.32/0.39	0.70/1.00	0.20/0.40	0.30/0.55	0.08/0.15	5
TS8137	0.35/0.40	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1, 3
TS8140	0.38/0.43	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
81B40	0.37/0.45	0.70/1.00	0.20/0.40	0.30/0.55	0.08/0.15	5
TS8142	0.40/0.45	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8145	0.43/0.48	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
81B45	0.42/0.50	0.70/1.00	0.20/0.40	0.30/0.55	0.08/0.15	5
TS8147	0.45/0.50	0.70/0.90	0.20/0.40	0.30/0.50	0.08/0.15	1
TS8150	0.48/0.53	0.75/1.00	0.20/0.40	0.35/0.55	0.08/0.15	1
81B50	0.47/0.55	0.75/1.05	0.20/0.40	0.35/0.60	0.08/0.15	5
TS8155	0.51/0.58	0.75/1.00	0.20/0.40	0.35/0.55	0.08/0.15	1
TS8160	0.55/0.62	0.75/1.00	0.20/0.40	0.35/0.55	0.08/0.15	1
TS8165	0.60/0.70	0.75/1.00	0.20/0.40	0.35/0.55	0.08/0.15	1
TS8615	0.13/0.18	0.70/0.90	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8617	0.15/0.20	0.70/0.90	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8620	0.18/0.23	0.70/0.90	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8622	0.20/0.25	0.70/0.90	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8625	0.23/0.28	0.70/0.90	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8627	0.25/0.30	0.70/0.90	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8630	0.28/0.33	0.70/0.90	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8632	0.30/0.35	0.70/0.90	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8635	0.33/0.38	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8637	0.35/0.40	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8640	0.38/0.43	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8641 (S)	0.38/0.43	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1, 6
TS8642	0.40/0.45	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8645	0.43/0.48	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS86B45	0.43/0.48	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	5
TS8647	0.45/0.50	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8650	0.48/0.53	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8653	0.49/0.55	0.75/1.00	0.40/0.70	0.65/0.85	0.08/0.15	1
TS8655	0.50/0.60	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS8660	0.55/0.65	0.75/1.00	0.40/0.70	0.55/0.75	0.08/0.15	1
TS94B17	0.15/0.20	0.75/1.00	0.30/0.60	0.30/0.50	0.08/0.15	5
TS94B20	0.17/0.22	0.75/1.00	0.30/0.60	0.30/0.50	0.08/0.15	5

NOTE 1 — An interim alternate (or tentative standard) steel designed to conserve nickel or molybdenum. They apply to hot rolled alloy steels generally not exceeding 200 sq.in. in cross-sectional area, or 18 in. in width, or 10,000 lb. in weight per piece. They also apply to alloy steel wire and to cold finished alloy steel bars.

NOTE 2 — For cold heading and cold forging wires, for making components up to and including ½ in. in diameter. A group of five grades is intended to provide material for a wide range of parts produced from alloy steel wire. For larger components, see NOTE 3.

NOTE 3 — For cold heading and cold forging wires, for making components over ½ in. in diameter and up to ¾ in. A group of four grades is intended to provide material for a wide range of parts produced from alloy steel wire. For smaller components use analyses under NOTE 2.

NOTE 4 — Designations with B are boron-treated steels, and can be expected to have 0.0005% min. boron content.

NOTE 5 — Boron-treated steels developed to conserve nickel and molybdenum, and can be expected to have 0.0005% min. boron content. Available as hot rolled alloy steels generally, alloy steel wire, and cold finished alloy steel bars.

NOTE 6 — Sulphur content of TS8123, 8126 and 8128 is 0.035 to 0.050; of TS8641 (S) is 0.040 to 0.060%.

Notes on Composition

Phosphorus and sulphur limits for each process are:

Basic electric, 0.025% max.
Basic openhearth, 0.04% max.
Acid electric, 0.05% max.
Acid openhearth, 0.05% max.

An exception is TS8641 (S), whose sulphur is 0.040 to 0.060%.

Silicon range for each of the steels listed here is 0.20 to 0.35%, except that when made in acid openhearth or acid electric furnace, the minimum is 0.15%.

Incidental Elements — Small quantities of certain elements are present in alloy steels which are not specified or required. These elements are considered as incidental and may be present to the following maximum amounts: Copper, 0.35%; nickel, 0.25%; chromium, 0.20%; and molybdenum, 0.06%.

Boron Steels*

THE METALLURGICAL ADVISORY BOARD was organized at the request of the Research and Development Board by the National Academy of Sciences, National Research Council, to advise the Research and Development Board of the Department of Defense on research aspects of some of the nation's most critical problems in metals. Within the limits of specific assignments it is to advise the Research and Development Board on the correlation, coordination, interpretation and application of metals research and development programs conducted or sponsored by the military services, suggest new projects or reorientation of existing research, and collect and distribute such useful metallurgical information as can be gathered through consultation with professional societies, Governmental agencies and appropriate academic and industrial organizations.

By the Panel on Substitution of Alloying Elements in Engineering Steels Metallurgical Advisory Board

In view of the widespread activity in the making and testing of boron steels, it appears desirable to bring together in one place the pertinent data and findings. The purpose of this report is to provide a factual summary of steelmaking practices, applications, and properties which can be used as a reference for furthering the applications of the boron steels and thereby conserving critical alloys. This information was obtained through a comprehensive survey of the literature and from unpublished reports and communications from the producers and users of boron steels.

The Panel on Boron Steels, Division VIII of the Society of Automotive Engineers, the manufacturers of ferro-alloys, and the alloy steel committee of the American Iron and Steel Institute, have pioneered the manufacture and applications. These groups have developed and standardized the boron steels on the basis of duplicating the hardenabilities of the present alloy steels. Application of boron steels to specific parts, such as gears, bolts, axles, and steering parts have been studied on the basis of response to manufacturing processes and service, or simulated service testing of finished parts. The many individuals and groups who have engaged in this research and development have contributed to our national security by establishing the foundation upon which these steels can be used as a potent means of conserving manganese, nickel, chromium and molybdenum.

INTERCHANGEABILITY OF STEELS

The present record-breaking production in the steel industry, accompanied by increased demands for engineering steels and alloys for high-temperature service, has created a serious shortage of several vital alloying elements. At present, nickel, molybdenum, tungsten, cobalt and columbium are in the "critical" category and it is not unlikely that chromium and manganese may also become scarce. The alloy shortage is *worse* now than in World War II because 30% more steel is being produced in the United States, second, military and ordnance requirements for alloy steels are increasing but have not yet reached their peak, and third, jet engines and gas turbines are requiring much highly alloyed materials to withstand service temperatures. Therefore, the "critical alloy" problem is not a temporary situation but should be considered as semipermanent because demands for these alloys will continue to increase and because (with the exception of molybdenum) domestic ore deposits are inadequate. Government controls and widespread substitutions are only temporary corrective measures and will not eliminate the basic cause creating the shortage.

Within the past few years it has been recognized that the physical properties of the engineering steels, such as tensile strength, yield strength, elongation, reduction of area, and hardness are dependent upon the microstructure of the steel. American metallurgists generally agree that all constructional steels, when quenched to 90 to 100% martensite and tempered, will have the same physical properties at any given hardness level within the range of 200 to 400 Brinell hardness number. This has been confirmed by the successful sub-

*The first report of the "Panel on Substitution of Alloying Elements in Engineering Steels" of the Metallurgical Advisory Board, the result of field work and meetings of the Panel and its subcommittees. The Panel has performed its functions in accordance with a contract between the Defense Department and the Signal Corps, which was negotiated at the request of the Research and Development Board. Membership is as shown on p. 88.

Issuance of this report does not necessarily represent concurrence of every member of the Panel in every statement of the report.

stitutions made during World War II when shortages of certain alloys were experienced. The data in Table I, interpolated from charts of physical properties for single heats, published by the producers of alloy steels, show that all the usual physical properties are nearly identical for an extremely wide range of analyses when compared at 150,000 psi. yield strength. At this strength, resistance to impact as measured by the Izod test also appears to be more dependent on carbon content than on any particular alloying element. The interchangeability of these steels exists at other strength levels and other section sizes, provided their microstructure is tempered martensite. As shown in Table I, the alloy content controls the tempering temperature necessary to bring the physical properties to a specific level.

Widespread *substitutions* for critically short nickel or molybdenum by using higher manganese or chromium contents will create, in turn, shortages in the latter. The prime objective is *conservation* of nickel, chromium, molybdenum and manganese by establishing the alloy content of all engineering steels at the lowest levels consistent with satisfactory performance in service. The tendency to substitute the A.I.S.I. 1300 series (1.60 to 1.90% manganese) for many of the low-nickel, chromium and molybdenum steels is therefore unrealistic and should be avoided because increasing the production of 1300 steels would drastically increase the consumption of manganese, and the diversion or stocking of off-heats (which occur more frequently when making medium-manganese steels) would result in loss of applicable ingot tonnage and waste manganese.

A major problem in the substitution of one engineering alloy for another is the determination of the necessary equivalence. There is seldom an exact and complete substitute available. The ordinary engineering tests are useful only as a guide after the properties which are related to performance have been defined. Before these time-consuming and expensive service tests are undertaken it is desirable to do some laboratory work to determine whether or not a complete test program is warranted. This involves both quantitative and qualitative considerations, tangible and intangible factors, and consequently demands real judgment.

Ordinary laboratory tests include the tensile test, hardness and hardenability. From these tests, the ultimate strength, the yield strength, the elastic modulus in tension, the ductility as measured by elongation and reduction of area of the test specimen, the hardness and the response of the steel to heat treatment can be measured quantitatively. The tests do not evaluate the steel's resistance to impact, behavior at low temperature or high temperature, response to compressive or repeated loading, its corrosion resistance, machinability, weldability, formability, wear resistance and other important characteristics. They do not evaluate the steel in terms of cost, availability, the use of alloying elements, and the ease of handling during fabrication. The proper evaluation of all the metallurgical, eco-

Table I — Comparison of Properties of Steels Heat Treated to 150,000-Psi. Yield Strength

Grade	Size Treated	Quench	Grain Size	Temper (°F.)	Analysis						Tensile Strength	Elong.	R. A.	Hardness	Izod Impact
					C	Mn	Si	Ni	Cr	Mo					
6130	1.00	Water	6 to 8	1025	0.33	0.61	0.18	—	1.03	(0.18 V)	160,000	18%	58%	C-37	61 ft-lb.
2330	0.530	Water	6 to 8	840	0.31	0.70	0.26	3.45	—	—	163,000	15	61	36	63
4130	0.530	Water	6 to 8	925	0.31	0.53	0.28	—	1.04	0.20	165,000	15	57	36	57
8630	0.530	Water	6 to 8	950	0.30	0.80	0.27	0.65	0.48	0.18	160,000	16	64	35	77
80B30	0.875	Oil	6 to 8	840	0.33	0.62	0.24	0.31	0.28	0.13	162,000	17	60	36	47
1340	0.565	Oil	6 to 8	925	0.43	1.70	0.23	—	—	—	160,000	15	55	36	52
3140	0.530	Oil	6 to 8	925	0.39	0.76	0.25	1.20	0.65	—	167,000	16	61	36	55
4140	0.530	Oil	6 to 8	1020	0.41	0.85	0.20	—	1.01	0.24	165,000	16	55	36	52
4340	0.530	Oil	6 to 8	1050	0.41	0.67	0.26	1.77	0.78	0.26	163,000	17	58	37	52
4640	0.530	Oil	6 to 8	975	0.41	0.70	0.24	1.83	—	0.28	163,000	17	56	37	49
8740	0.565	Oil	6 to 8	1100	0.39	1.00	0.25	0.53	0.52	0.28	160,000	16	57	35	61
9440	0.530	Oil	6 to 8	925	0.39	1.06	0.28	0.39	0.32	0.11	165,000	16	59	36	58
4150	0.530	Oil	7 to 8	1160	0.50	0.76	0.21	—	0.95	0.21	165,000	15	54	37	46
5150	0.530	Oil	7 to 8	1000	0.49	0.75	0.25	—	0.80	—	160,000	15	53	35	39
6152	0.565	Oil	6 to 8	1125	0.49	0.78	0.29	—	1.00	(0.17 V)	160,000	16	51	35	46
8750	0.530	Oil	6 to 8	1040	0.51	0.80	0.24	0.53	0.52	0.25	166,000	14	50	37	50

nomic and engineering factors is of the utmost importance, since proper selection will result in a steel the properties of which will permit adequate performance in service and will not be wasteful of alloys.

The present shortage of alloying materials and the likelihood that this shortage will continue demands that specifications, engineering designs, and metallurgical practices be reviewed to determine the minimum physical properties required for adequate service performance and the minimum alloy content which will insure these required properties. The continued extravagant use of nickel, chromium, molybdenum and manganese will impair our economic and political security because, with the exception of molybdenum, domestic resources are inadequate or nonexistent and we are, therefore, dependent on friendly foreign governments and open shipping lanes to satisfy our requirements. Fortunately, as the result of metallurgical research during the past 10 years, and industrial development and application of improved heat treating practices, we are in a position to intelligently reduce the total alloy content of many components without impairing service performance. In fact, in many instances service performance has been improved. Induction hardening and flame hardening techniques have often entirely eliminated the need for highly alloyed steels in many machine parts because plain carbon steels, when treated by these methods, have proven to be adequate. Also, insofar as the heat treating steels are concerned, the potentialities of the element boron for increasing hardenability, and thereby reducing the total alloy requirements, have not been fully explored — but experience thus far has shown that savings in alloys can be obtained thereby.

CONSERVATION OF ALLOYS BY INDUCTION HARDENING

Induction hardening techniques have been successfully applied to intricate or massive components produced in large volume where uniform strength or hardness, throughout the entire section, are neither required nor desirable but where high strength or hardness in certain sections of the component is essential to service requirements. Examples given in Table II (from three individual companies) illustrate its effectiveness as a means of conserving alloys while required physical properties are maintained or even improved.

There are many other applications of induction and flame hardening (differential or localized hardening) but these three outstanding examples are sufficient. Unfortunately, differential hardening methods are not universally

Table II — Conservation of Alloys by Induction Hardening

Part	A.I.S.I. Grade	Specification (Mean)				
		C	Mn	Ni	Cr	Mo
Automotive crankshafts*						
Former grade	3140	0.40	0.80	1.25	0.65	—
Induction hardened grade	1045	0.46	0.75	—	—	—
Automotive axles†						
Former grade	4140	0.40	0.87	—	0.45	0.20
Induction hardened grade	1035	0.35	0.75	—	—	—
Tractor main drive gears‡						
Former grade	2345	0.45	0.80	3.50	—	—
Induction hardened grade	1045	0.45	0.75	—	—	—
Amount of alloy saved annually						
Automotive crankshafts	15,500 ingot tons		22,000 lb.	398,000 lb.	200,000 lb.	—
Automotive axles	15,500		50,000	—	295,000	62,000 lb.
Tractor main drive gears	10,000		16,000	700,000	—	—
Totals	41,000 ingot tons		88,000 lb.	1,098,000 lb.	495,000 lb.	62,000 lb.

*Crankshaft body is normalized; bearing surfaces induction hardened.

†Induction hardened shafts have surface in compression and surface hardness at C-42 to 48. Shafts formerly were oil quenched and tempered to C-32 to 35.

‡Gear teeth treated to higher hardness by induction hardening than formerly possible when oil quenching the entire gear.

applicable, being most amenable to symmetrical sections and to mass production of similar sized parts. However, in view of the present critical shortage of alloys and the probability that this situation will continue for some time, it is in the interest of national security that localized hardening methods should be expanded in order to conserve critical alloys.

CONSERVATION OF ALLOYS BY THE USE OF BORON

Our present knowledge of the behavior of boron in steel is far from complete; every day we are learning more about it. Large industrial use of boron as an alloy began in the latter part of World War II. However, its effect had been known for about 15 years but was not widely recognized until the early part of World War II when the correlation of hardenability with chemical composition became an invaluable tool for measuring the boron effect and aided in devising alternate steels.

As far as is known the first commercial heats of boron steel were made in 1937 by the Wisconsin Steel Co. and from that time until January 1951 the steel industry has produced 410,000 ingot tons of boron-treated steels, exclusive of those used as armor plate. A large portion of this tonnage has been used by three consumers who early recognized that lower net production costs would be obtained with them. In addition, large amounts of alloying elements have been saved for use in essential applications where equivalent, leaner alloy steels have not been developed. The large tonnage of boron steels successfully used by these three companies, as given in Table III, indicates their reliability and their effectiveness in conserving alloys without adversely affecting physical properties or safe performance. Although the hardenabilities of 14B35 versus 8637, and 14B50 versus 4142 are not equivalent for all section-sizes, nevertheless the hardenabilities can be considered as equivalent within the range of small section-sizes shown in Table III for Company B (item 2) and for Company C. The total saved annually by the four uses cited in Table III is 9100 lb. manganese, 701,000 lb. nickel, 86,000 lb. chromium and 30,000 lb. molybdenum.

Table III — Conservation of Alloys by Use of Boron Treatment

Item		Analysis*		Pounds Annually	
		Former Grade	Boron-Treated	Saved	Expended
Company A		4820	43B17		
Gas carburized	C	0.20	0.17		
heavy duty	Mn	0.60	0.55	10,700	—
gears (10,700	Ni	3.50	1.75	375,000	—
annual ingot	Cr	—	0.50	—	107,000
tons)	Mo	0.25	0.25	—	—
	V	—	0.04	—	—
Company B		2345	86B45		
6-in. diameter axle	C	0.45	0.45		
and clutch shafts,	Mn	0.80	0.87	—	4,000
and steering	Ni	3.50	0.55	325,000	55,000
knuckles (5500	Cr	—	0.50	—	22,000
annual ingot tons)	Mo	—	0.20	—	
Company B		8637	14B35		
Bolts, studs, cap	C	0.39	0.35		
screws (max. 1¼ in.)	Mn	0.87	0.75	2,400	
(1000 annual	Ni	0.55	—	11,000	
ingot tons)	Cr	0.50	—	10,000	
	Mo	0.20	—	4,000	
Company C		4142	14B50		
Hand tools for	C	0.42	0.46		
mechanics (12,000	Mn	0.87	0.87	—	
annual ingot tons)	Cr	0.95	—	238,000	
	Mo	0.20	—	48,000	

*Mean value of specification.

One consumer reports that steel mills have generally been as successful in providing boron-treated steels of uniform quality, throughout the delivered lot, as with any other alloy steel. In addition, fewer rejections of mill heats have been encountered with boron-treated steel, from several sources, than for the comparable grades which they replaced; furthermore, during ten years of field performance, they have as yet to ascribe the cause of failure of any returned part to the fact that boron was used as an alloying element of the steel.

BORON AGENTS AND METHODS OF ADDITION

There is general agreement about the amount of boron required and the most effective practice for insuring its retention in the steel. Additions are generally made in the ladle, although additions to the mold can be equally effective (but,

from a steelmaking standpoint, somewhat more difficult to control).

For optimum results in the steel mill the boron addition should be made to a fully deoxidized, fine-grained steel. It has been well established that boron tends to increase the austenitic grain size of steel but this can be overcome by increasing the amount of aluminum or other strong deoxidizers 20 to 30% above the amount normally required. As boron is itself a rather efficient deoxidizer, it is advisable to protect it by first adding two thirds or three quarters of the required ladle deoxidizers, and the remainder with or following the boron.

There are numerous agents by which boron may be added to steel and all are equally effective if good steelmaking practice is followed. Some of the complex alloys contain strong deoxidizers such as aluminum, calcium, titanium, or zirconium and these complex alloys can sometimes adequately control the grain coarsening tendencies of boron without the use of extra aluminum. In this respect they have a definite advantage to the steelmaker. Table IV shows the nominal analysis of most of the commercial products which have been used or are now available.

Table IV — Nominal Analyses of Boron Agents

Element	Grainal			Silvaz	Silcaz	Carbortam	Bortam	Borosil	Ferroboron		Manganese-Boron
	No. 1	No. 6	No. 79						Mfr. A	Mfr. B	
Boron	0.2	0.2	0.5	0.6	0.6	1.5	1.7	3.5	12	>17.5	17
Silicon	3	—	5	37	37	3	21	40	1	1	1
Aluminum	10	12	13	6	7	1.5	14	—	—		—
Titanium	15	20	20	10	10	17	17	—	—		—
Zirconium	—	—	4	6	4	—	—	—	—		—
Calcium	—	—	—	—	10	—	—	—	—		—
Vanadium	25	13	—	10	—	—	—	—	—		—
Manganese	—	—	8	—	—	—	23	—	—		75.0
Carbon	—	—	—	—	—	6	—	—	<0.5		<3.0
Iron	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.	Bal.		<5.0

Indications are that optimum effects are obtained when the size of the addition introduces from 0.0008 to 0.003% boron into the through-hardening steels (one third ounce to one ounce per ton). Under some conditions even smaller amounts have been effective. There are indications that hardenability is increased in proportion to the boron up to about 0.001% B but beyond this value the hardenability is not affected very much. Steels with higher contents have been satisfactory but in such steels the limiting content with respect to hot shortness is more closely approached. In the low-carbon steels the optimum effect is obtained at somewhat higher boron contents, and the proportional effect appears to continue above 0.003% B.

The amount of agent which is to be added can be conveniently expressed in pounds of alloy per ton of ingots. These values, as shown in Table V, have been developed by the steel producers as the approximate levels at which consistent results can be obtained with the respective agents. For the low-carbon carburizing grades made in the openhearth, and all engineering alloy steels made in the electric arc furnace, the amount of boron agent must be increased approximately 50% above the values given in Table V, and occasionally more.

There is no danger of exceeding the limit of hot shortness in normal steelmaking operations if the boron content of the addition agent is well

Table V — Amount of Boron Agents per Ton of Ingots
(for intermediate carbon steels)

Agent	Boron in Agent	Addition per Ton	Boron Added to Steel
Grainal No. 1	0.2%	4 lb.	0.0004%
Grainal No. 6	0.2	4	0.0004
Grainal No. 79	0.5	4	0.0010
Silvaz	0.6	4	0.0012
Silcaz	0.6	4	0.0012
Carbortam	1.5	3	0.0023
Bortam	1.7	3	0.0026
Borosil	3.5	2	0.0035
Ferroboron	12.	0.8	0.0048
Manganese-boron	17.	0.4	0.0034

Supply of Necessary Ferro-Alloys

established and controlled within reasonable limits. However, the nominal boron content of the available agents varies from 0.2% for Grainal No. 1 to 17.5% min. for one grade of ferroboron. From a steelmaking standpoint this wide range is very undesirable, since steelmaking practices must be established for each proprietary alloy, and unless the supply is balanced with demand, the steel producers must alter practices in order to use whatever one is available.

This unrealistic condition does not exist in other ferro-alloys and steps should be taken to standardize or to reduce the number of commercial agents to the minimum. This might well result in one agent of the low-boron, complex type, and one agent of the high-boron type. This agent is to some extent dependent upon the grade of steel produced. Agents of complex type are generally preferred for low-carbon (under 0.30% C) and electric furnace grades because the supplementary alloys in these agents (vanadium, zirconium, titanium, aluminum, calcium) aid in fixation of the high nitrogen and oxygen in the melt. In steels containing above 0.30% carbon the simple agents, such as ferroboron or Borosil, can be used effectively. (When they are used for the low-carbon grades they should be fortified with supplementary alloys such as aluminum, zirconium or titanium.)

The above-mentioned melt schedule for March 1943 was critically analyzed to determine the amounts and types of boron agents required to treat the entire tonnage effectively. The result is summarized in Table VI and shows that the supply of simple agents is more than adequate to treat the expected tonnage of alloy steels containing over 0.30% carbon, but that a deficiency exists with respect to the availability of the complex agents, with and without vanadium, for treating the necessary tonnage of low-carbon alloy steels.

Table VI — Agents Needed for 10,000,000 Tons Alloy Ingots Yearly
(based on melt schedules for March 1943)

Alloy Grade	Ingot Tons		Boron Treatment		Total Pounds	
	Mar. 1943	Annual Rate	Agent	Lb./Ton	Required	Available*
Over 0.30% C	615,000	7,300,000	Simple	0.8†	5,800,000†	9,500,000†
Below 0.30% C	136,000	1,600,000	Complex	6.0	9,600,000	7,000,000
Below 0.30% C	74,000	900,000	Complex (with vanadium)	6.0	5,400,000	3,000,000

*Annual capacity of ferro-alloy manufacturers of this grade (1951).
†Based on ferroboron or its equivalent weight as Borosil.

ideal objective may not be attained for some time, but development work is already under way. Combined facilities for producing these five agents are probably adequate to meet the requirements for treating 10,000,000 ingot tons annually.

Predictions that 10,000,000 ingot tons of alloy steel will be needed in one year are very realistic. In the peak month of March 1943, the melt schedules required the production of 825,000 tons of alloy grades (an annual rate of 9,900,000 tons), all of which was amenable to boron treatment. In addition 236,000 tons were scheduled which are not responsive to boron treatment — that is, stainless, toolsteels, low-alloy high-strength plate. This same tonnage could not be produced today, grade for grade, because enough nickel and molybdenum is not available. However, it is quite likely that this same *total* tonnage will be required and can be met by using leaner alloy steels treated with boron to give equivalent hardenability.

Selection of the amount and type of addition

The data in Table VI are based entirely on requirements for treating *alloy* steels. Boron can conceivably be used to replace a part of the manganese in what is now a considerable tonnage of intermediate carbon steels, consumed in ordnance or civilian uses, which are liquid quenched and tempered to meet specific physical properties. Boron treatments have not been extended to these applications but if such treatments are found to be practical, or become necessary in order to conserve manganese, the available supply of the simple agents would be inadequate. For example, if 10,000,000 tons of carbon steels are replaced with boron-treated steels, in addition to the 10,000,000 tons of alloy steels, there will be a 5,000,000-lb. shortage of the simple type of agent (ferroboron or its equivalent weight of Borosil).

Implications of Equivalent Hardenability

In view of the definite possibility that applications of boron-treated steels will be expanded, it is essential that the ferro-alloy manufacturers be kept accurately informed of all proven and proposed applications so that production facilities for addition agents can be expanded in line with requirements.

HARDENABILITY

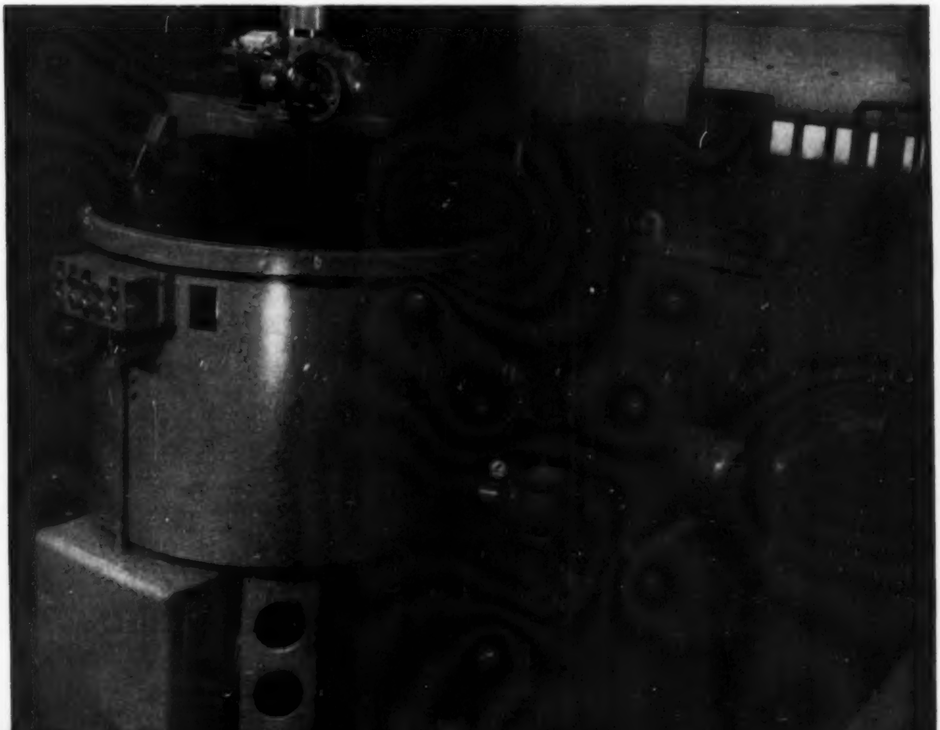
As a result of contributions from many workers during recent years, it is relatively easy to predict with some degree of accuracy the hardenability and tensile strength as well as the impact strength of a steel. These, and closely related properties such as yield strength and fatigue strength, are primary factors in determining serviceability of quenched and tempered steels. The basic concepts of hardenability established by various investigations show that, for all practical purposes, the physical properties concerned with strength are directly proportional to the hardness, and the alloy content is of importance primarily in influencing the reaction to heat treatment — hardening and tempering operations. Since the alloying elements have no *specific* effect on the strength properties for ordinary use in machines, it is logical that steels with similar hardenabilities may be used interchangeably without loss of serviceability.* (This has been confirmed by the successful substitutions made during World War II.) Thus,

*Editor's Footnote — In a panel discussion at 1951 Western Metal Congress, reported in *Metal Progress* for June 1951, Walter E. Jominy, president ⊜, and staff engineer, Chrysler Corp., was asked this question:

"Is it true, Mr. Jominy, that steel A which has a certain hardenability band is equivalent in its use and mechanical properties to steel B which has the same hardenability band, even though it may be far distant from it in chemical composition?"

Mr. Jominy replied: "From the standpoint of mechanical properties it is, if you are interested in hardnesses between 200 and 400 Brinell, provided you have first hardened each of the steels to give you a microstructure of at least 90% martensite. After drawing back to equivalent hardness, then the properties are usually quite comparable. There are some small differences, but they are usually insignificant."

Modern Unit for Induction Hardening and Quenching Large Drive Gear for Caterpillar Tractors. Many economies result from use of plain carbon steel for this important part rather than 3½% Ni steel formerly used. Photo courtesy Ohio Crankshaft Co.



Boron's Enormous Potency

after the desired tensile and impact strength is determined, the selection of a specific steel should be based on the *lowest* combination of critical alloys required to give those properties.

Boron is used in steel for only one purpose — to increase hardenability and to thereby replace other alloys such as manganese, nickel, chromium and molybdenum. Its behavior is unique in that the increase in hardenability for all practical purposes appears to be independent of the amount of boron present, above the usual minimum value of 0.0008%, and also in that it can replace several hundred times its own weight of nickel, chromium, molybdenum or manganese.

Furthermore, boron steels are peculiar since, at approximately eutectoid composition, boron appears to have little or no effect on hardenability. However, as the carbon *decreases* below the eutectoid composition the effectiveness of boron *increases* linearly. G. D. Rahrer and C. D. Armstrong ("The Effect of Carbon Content on the Hardenability of Boron Steels", *Transactions* ⊕, V. 40, 1948, p. 1099) have expressed this relation by a linear equation for microstructures with 50% martensite:

$$F_B = 1 + 1.5\ (0.90 - C)$$

where F_B = multiplying factor for boron
C = per cent carbon

This equation is only applicable to fine-grained, thoroughly deoxidized steels which contain at least 0.0008% boron. When both these conditions are met the reproducibility of the effectiveness of boron can be considered as statistically assured.

The fact that boron is quite potent at low carbons is of particular importance because the most highly alloyed heat treating steels are below 0.30% carbon. These include the A.I.S.I. series 23xx, 25xx, 33xx, 48xx and 93xx. The 43xx series is also highly alloyed and is not produced as a standard grade above 0.40%. These six grades are fertile fields for conservation of critical alloys and several boron-treated steels have been tested, both in laboratory and in service, to determine alternate grades with equivalent hardenabilities and service performance.

An unfortunate dilemma exists at the present time which is temporarily restricting immediate applications. Consumers will naturally hesitate to order these steels in large tonnages until hardenability bands have been definitely established. On the other hand, the American Iron and Steel Institute must have a reasonably large tonnage of each grade produced and tested before a statistically reliable band can be established for it. In the interim, sound metallurgical judgment is required in selecting boron-treated grades as alternates for existing and service-tested applications of the higher alloyed steels.

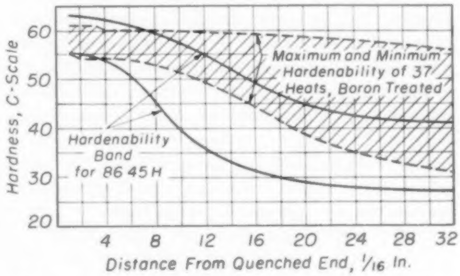


Fig. 1 — Specified Hardenability Band for 8645H and Maximum and Minimum Limits for 37 Heats Steel Melted to Same Analysis but Boron Treated

Best Field Is in Lean Alloy Steels

There are very few steels which are produced both with and without boron because the boron grade has been specially designed to have hardenabilities equivalent to those of higher alloyed steels.

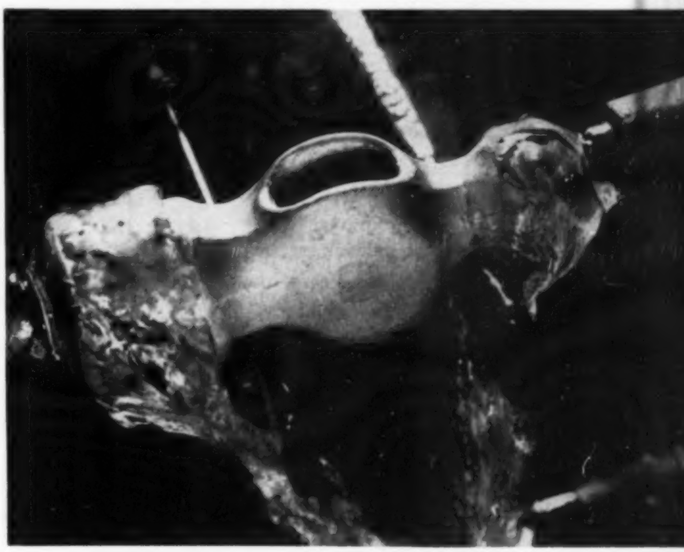
Actually, comparison of hardenabilities of the same grade, with and without boron, provides no information which would be useful in selecting alternate grades, since it merely demonstrates the potency of boron upon the known hardenability of one given grade. As an example, Fig. 1 shows the data for 8645. The maximum and minimum hardenabilities encountered on 37 heats of 86B45 are compared with the standard A.I.S.I. hardenability band for regular 8645. Obviously this comparison does not indicate, except in the most general way, the extent to which boron can conserve critical alloys.

The most useful comparisons are those showing the hardenabilities of a lean alloy, boron-treated grade and the closest matching higher alloyed grade. Such matching will be greatly simplified when sufficient data have been accumulated so that standard and accepted hardenability bands can be established for all boron-treated steels. The hardenability experience limits to date of writing for numerous heats of 11 boron-treated grades are shown in Fig. 2 to 6. In each diagram the maximum, minimum and mean hardenabilities obtained are indicated by the shaded areas, and the heavy lines indicate the hardenability bands of standard A.I.S.I. grades without boron. The hatched areas are in no way intended as standards.

Boron steels generally tend to have wider limits between the maximum and minimum hardenabilities than those without boron, as is demonstrated in Fig. 1. However, this spreading usually occurs beyond the Jominy distance corresponding to 50% martensite and therefore is generally considered unimportant. This condition is natural in that all normal variations in hardenabilities, within the full analysis limits of a grade, are expanded in proportion to the magnitude of the boron factor, F_B, which, as mentioned earlier, increases from a value of 1.0 at about 0.90% carbon to 2.2 at about 0.20%. This is not necessarily alarming nor need it be considered as evidence that the boron steels are inferior or lack reproducibility. Except for the intermediate-carbon boron-treated steels, shown in Fig. 2, the agreement in hardenabilities is quite good up to a Jominy distance of 10/16, which corresponds to the center hardness of a 2½-in. round quenched in water, or a 1¾-in. round quenched in oil.

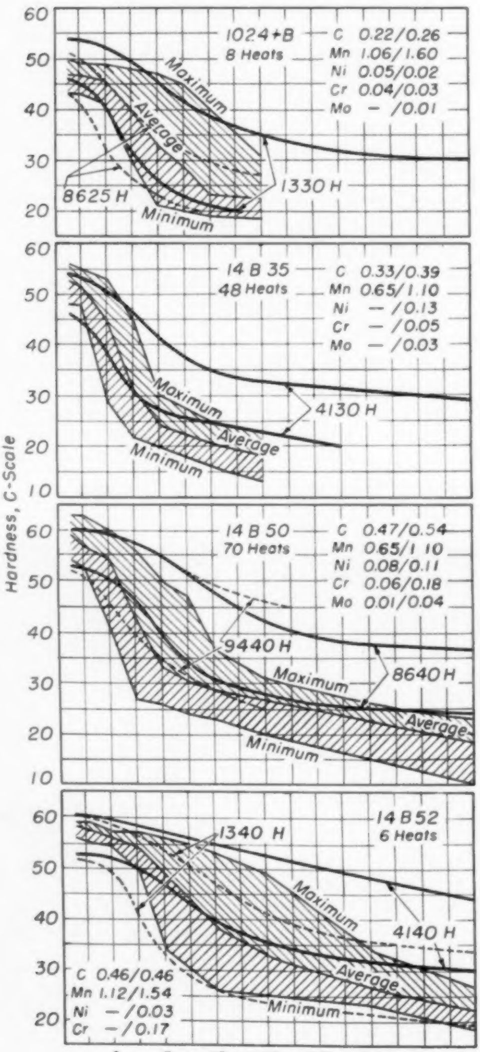
It is not necessary for equivalence of hardenability to extend over the entire range of the hardenability bands in order to select a suitable boron-treated steel. Equivalence is only necessary to the extent dictated by the section size of the part to be hardened; deviations at larger section sizes are irrelevant. For example, Fig. 2 (second from top) shows that the hardenabilities of 14B35 and 4130H are only equivalent up to a Jominy distance of 4/16, but this corresponds to the center hardness of a 1¼-in. round quenched in water, and slightly over a ½-in. round quenched in oil. As shown in Table III, p. 84, several thousand tons of satisfactory bolts and cap screws have been produced from this analysis, 14B35, where the former grade was alternately 3140 or 4140. As 14B35 is lower in hardenability than 3140 or 4140, this change involves the use of a lower

Put the High Properties Where They Are Really Needed! "End-quenching" heads of a ball-peen hammer. Photo at Plomb Tool Co. by H. L. Millar



hardenability steel, requiring a change in practice to water quenching sizes from 7/8 to 1¼ in., and to lowering tempering temperatures slightly in order to maintain a specified tensile strength

Fig. 2 — Hardenability Experience for Four Intermediate-Carbon Steels, Boron Treated



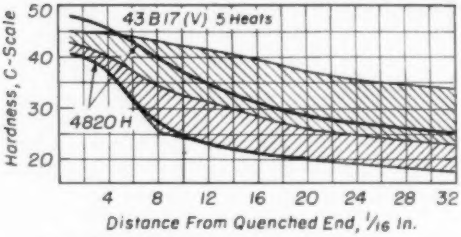


Fig. 3 — Hardenability Experience for a Nickel-Chromium-Molybdenum Steel, Boron Treated. Analysis: 0.14 to 0.20% C, 0.45 to 0.70% Mn, 1.65 to 2.00% Ni, 0.35 to 0.60% Cr, 0.20 to 0.30% Mo, 0.03% min. V

of 150,000 psi. minimum. The wide deviations in comparative hardenabilities of grades 14B35 and 3140 or 4140 beyond the limit of 1¼ in. from the quenched end, have in no way affected service performance of the bolts.

A better understanding of the behavior of boron steels during conventional heat treatments such as quenching, normalizing, and annealing can be obtained from studies of the isothermal transformation diagrams. The few studies which have been made show that the beginning of transformation is delayed at the "nose" of the curve, but that the time required to complete the transformation is practically unchanged. Boron, therefore, increases the incubation period but does not drop the temperature nor decrease

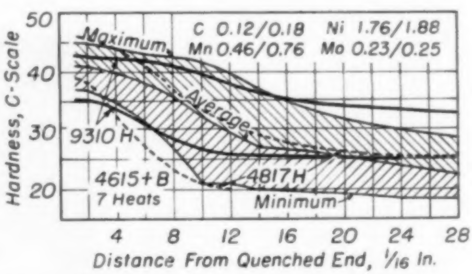


Fig. 4 — Hardenability Experience for Boron-Treated Nickel-Molybdenum Steel 4615 + B. A good substitute for 4817H

the rate of transformation at which pearlite and ferrite form subsequently, whereas the conventional alloying elements shift both the start and completion of transformation toward longer times and toward lower temperatures.

These facts explain why boron increases hardenability, but has no power to produce the finer pearlite and the higher strength in normalized steels, such as is obtained by addition of one

Low-Temperature Draw Desirable

or more of the conventional alloying elements. This has a practical application in that a lower alloy steel containing boron can replace a higher alloyed steel to obtain the same properties when hardened, yet the boron steels can be annealed with a much shorter cycle and are also softer than the higher alloyed steels in the as-rolled or normalized condition (provided the section is sufficiently large that air hardening cannot occur).

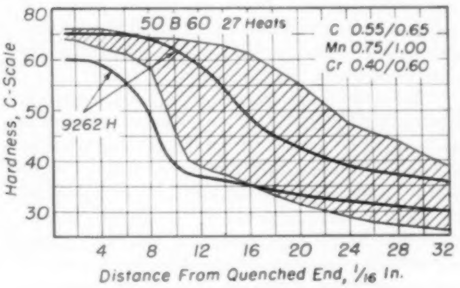


Fig. 5 — Hardenability Experience for Boron-Treated Chromium Steel 50B60

LIMITATIONS OF BORON-TREATED STEELS

All characteristics of these steels have by no means been fully investigated and caution should be exercised in certain respects. For example, it has been reported that boron increases sensitivity to temper brittleness. Although the condition does not at present appear to be serious, nevertheless it is advisable to avoid tempering them above 1000° F. until it has been established whether the effect is caused by the presence of boron or is attributable to the lower molybdenum. When necessary to temper above 1000° F. in order to obtain specific physical properties, the hazard of encountering temper brittleness can be avoided by liquid quenching after tempering. As boron has little or no effect in retarding softening at elevated temperatures, these steels should be tempered at 50 to 150° lower temperatures than are usually necessary to attain a desired hardness or strength, depending upon the change in the alloy content of the base analysis.

Boron cannot perform the same function as molybdenum, vanadium, or tungsten of contributing resistance to creep when stressed at

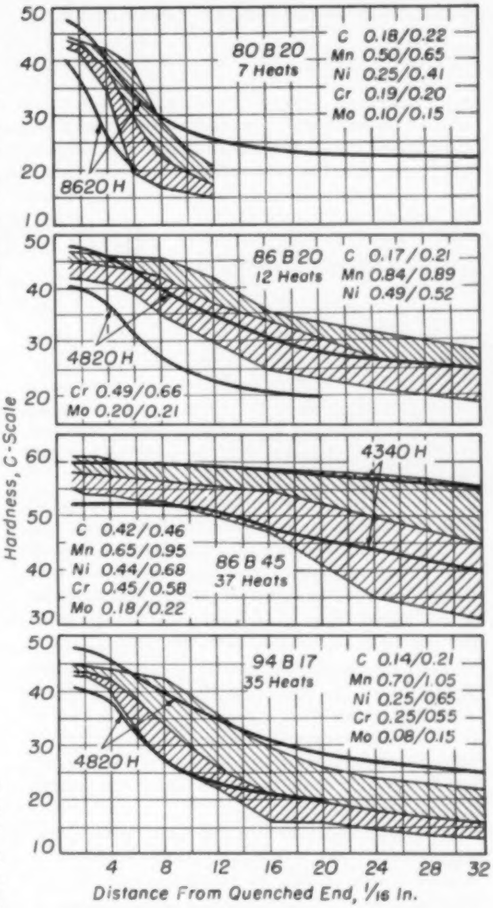


Fig. 6 — Maximum, Minimum and Average Hardenability of Four Triple-Alloy Steels, Boron Treated

elevated temperatures. Therefore, it is not considered practical to use boron to replace these elements in steels designed for high-temperature service.

Conflicting reports have been made in regard to the effect of boron on the notch toughness of steels with a microstructure of tempered martensite, especially at low temperatures. The impact strength of the boron steels at −20 to −40° F. can usually be held within the ductile fracture range and, if notches are avoided in designs, service performance of these steels at low temperatures will probably be satisfactory. When it is known that equipment must operate at low temperatures, suitable laboratory and

Low Alloy Means Easy Fabrication

prototype tests should determine the minimum impact strength which will meet service requirements. Without this information it is impossible to say whether or not the impact strength at low temperatures is adequate to prevent failure in service.

OTHER PROPERTIES OF BORON STEELS

In considering the performance of any steel in production the very important fabricating properties, such as rolling and forging, must be thoroughly scrutinized. Boron steels respond to rolling and forging in the same manner as steels of similar base analysis, without boron, provided the content is below the level at which hot shortness occurs.

The type of scale formed on heating is entirely dependent upon the *base* analysis, and this asset has not received adequate emphasis. The ability of boron to replace several hundred times its own weight of nickel, chromium, molybdenum and manganese, makes possible the use of plain carbon or lower alloyed steels without sacrificing hardenability or the physical properties of the part, heat treated and finished. The light, flaky scale formed on heating can be more readily removed and has less tendency to adhere and be driven into the surface of the billet or forging than it is on the more highly alloyed steels.

Boron steels, because of their lower total alloy content, are believed to be less sensitive to shatter cracks and flakes as are the more highly alloyed steels. Thus, blooms or forgings of boron-treated steel may require no additional pit cooling or controlled cooling, beyond the normal care required for the base analysis without boron.

These generalizations concerning hot working properties apply to all other properties of these steels. In general, the properties are characteristic of the base analysis without boron. For example, normalizing and spheroidizing operations are not affected by the presence of boron in a steel of given alloy content. Likewise, rates of carburization and decarburization are unchanged.

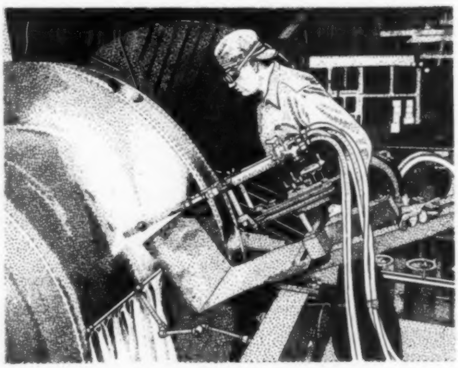
Some users of large tonnages of boron steels have reported that weldability, machinability, cold heading and cold bending properties are unchanged and can be predicted from the behavior of the base analysis without boron.

SUMMARY

Boron is used in steels for only one purpose — to increase hardenability. By its effect on hardenability, it can drastically reduce the amount of nickel, chromium, molybdenum, and manganese ordinarily used to increase hardenability. The amount of boron required to assure optimum results in the steel lies between 0.0008 and 0.003% for the intermediate-carbon steels, and may be above this range for the low-carbon steels. The large tonnage successfully used during the past 10 years indicates their reliability and their effectiveness in conserving alloys without adversely affecting physical properties or safe performance. From the standpoint of national security, their use should be immediately expanded to conserve alloys conventionally used to increase hardenability.

Because of its tendency to form carbides, nitrides, and oxides, the boron added to molten steel must be protected by prior additions of strong deoxidizers sufficient to produce a thoroughly killed, fine-grained steel. When producing electric furnace steels or openhearth grades with less than 0.30% carbon, it has been found advisable to use complex addition agents which contain carbide or nitride-forming elements, or to use the simple boron agents together with titanium, zirconium or aluminum.

The various agents available for introducing boron into steel vary widely in boron content, and consolidation to a minimum number of standard grades is under consideration. Boron ores are abundant in the United States, but the present furnace capacity available for production of the addition agents, without interfering with production of other ferro-alloys, is only adequate to provide materials sufficient to treat 10,000,000 ingot tons of steel annually.



ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Company, a Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

High-Chromium, High-Carbon Iron

. . . the Iron That Hardens as it Wears

In many applications involving extreme abrasion, ordinary work-hardening alloys are not suitable. This is because most of these alloys require a definite pounding action for a martensite transformation, and the scouring action of an abrasive is not sufficient for development of high wear resistance. For this reason, high-chromium, high-carbon irons were developed – irons that wear-harden.

Chromium Content of Irons Ranges from 24 to 30 Per Cent

These irons are made in the electric furnace and have the following composition range:

Chromium	26 to 28 per cent
Carbon	2.60 to 2.80 per cent
Manganese	0.50 to 1.25 per cent
Silicon	0.25 to 0.75 per cent
Sulphur	max. 0.05 per cent
Phosphorus	max. 0.05 per cent
Nickel	minimum
Iron	balance

Irons of this composition are readily castable by steel casting techniques.

Development of Greater Wear Resistance by Heat Treatment

Structurally, these irons consist of primary iron-chromium carbides in a matrix of iron-chromium solid solution and secondary iron-chromium carbides. They are hard in the as-cast condition (500 to 550 Brinell), but when they are given an austenitization heat-treatment they develop much higher hardness (about 600 Brinell), and also have greatly improved wear resistance. Austenitization consists of heating these irons to a temperature of about 2012 deg. F. for an hour, then allowing them to cool in air. This heat-treatment promotes the formation of very unstable austenite—austenite that will transform to a harder martensitic end-product even under rubbing or mild impingement action. Austenitization has been found to be far more effective in increasing wear resistance than the promotion of unstable austenite by the addition of ferrite-forming alloying elements.

High-chromium, high-carbon irons can also be annealed to sufficiently low-hardness values for grinding or simple machining. Hardnesses as low as 350 to 450 Brinell can be obtained by heating the castings to temperatures of 1400 to 1450 deg. F. for 12 to 24 hours, then allowing them to cool in air.

Irons Have Wear Resistance Many Times That of Other Alloys

Austenitized high-chromium irons have been known to last as much as 21 times longer than other wear-resistant alloys in applications involving extreme frictional abrasion. These applications include sandblast nozzles and liners, pantograph contact shoes, grinding disks, pulleys, chute-liner plates, dredge-pump liners, and rollers for crushing various hard materials.

In a recent test, high-chromium iron was compared to special wear-resistant steel castings as the material for hammers in a machine that was used to crush abrasive material. The chrome-iron hammers were found to have almost 7 times the wear resistance of the steel castings.

Fig. 1. After crushing the same amount of abrasive material in a hammer mill, the badly worn steel casting (left) had a weight loss of 37 per cent while the high-chromium iron casting (right) lost only 5.5 per cent.

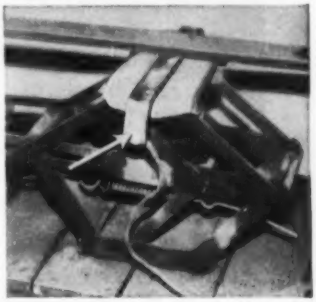


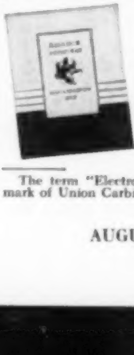
Fig. 2. This chrome-iron pantograph shoe had a service life of about 10 years. A tool steel that was used in similar service wore out in about 3 or 4 months; copper lasted about 24 hours.

When thoroughly backed up with zinc, the iron also has enough shock resistance to be used effectively as crushing hammers and jaw plates for many severe rock-handling jobs.

Metallurgical Service Available

For years, ELECTROMET high-carbon ferrochrome has been used to make chromium additions to abrasion-resistant high-chromium irons. If you should have any questions about either the production or use of these irons, write to the nearest ELECTROMET office. Our metallurgists will be glad to give many valuable suggestions and recommendations on how to make or use this iron most effectively.

Write for a free copy of the ELECTROMET publication, "Abrasion-Resistant High-Chromium Iron." This booklet is a collection of some of the best available information on how to make and to use abrasion-resistant iron castings most efficiently.



Personal Mention

G. Wirrer

Marshall H. Medwedeff

G. Wirrer, after 45 years of metallurgical service in the automotive industry, has recently retired from the Mack Manufacturing Co., Plainfield, N. J. A native of Switzerland, Mr. Wirrer started in the industry in 1905 as a foreman with the Sauer Motor Co., Arbon, Switzerland. He came to America in 1911 and was employed by the International Motor Co., Plainfield, now a subsidiary of Mack Trucks, Inc., as an instructor and later became chief inspector. He was instrumental in bringing about many of the improvements made on automotive products over the years, especially the Mack engines. The heat treating department, which was simply the blacksmith shop when he started to work, interested Mr. Wirrer and, in order to bring up the standards of operation within that neglected department, he took a correspondence course in metallography with Sauveur & Boyleston, graduating in 1918. Since that time some of the 28 patents he has been granted have been for heat treating furnaces, gear testing and gear grinding machines, and an automatic ignition control for gasoline engines. In 1940 he was granted the Modern Pioneer Award from the National Association of Manufacturers. Mr. Wirrer was a member of the American Steel Treaters' Society and has been an American Society for Metals member for over 30 years.

One of the widest-known members of is "Med" — and for good reason. A charter member, clear back to the days when the Buffalo Chapter of the American Steel Treaters Society was formed, he has taken an active part in Chapter affairs and has seldom if ever missed an annual convention. All will wish him God-speed, long life and success as consultant, after 26 years as metallurgical engineer for A C Spark Plug Division of General Motors Corp.

Medwedeff graduated from the University of Pennsylvania in 1911 but soon found he needed special training in metallurgy, so he spent 1915 and 1916 studying under Albert Sauveur at Harvard. From then on, as he likes to say, he "gathered a lot of polish but not moss, and had a lot of fun metallurging". He organized heat treating departments and laboratories for Samson Tractor Co., Janesville, Wis., Wyoming Shovel Works, Wyoming, Pa., and finally for A C Spark Plug, Flint, Mich.

The early *Journals* of the Society, as well as *Metal Progress*, contain brief but meaty papers from him on heat treatment of high speed steel, metallurgical inspection, metallurgy in a modern shop, and workability of high-brass sheet.

In 1924, when Medwedeff started at A C Spark Plug, all that the plant was making was just that — spark plugs. He contributed largely to the production of quality magnets from the early models to the present. The heat treatment of the speedometer spindle required intensive study. Then came extensive installations for die casting zinc, lead and tin alloys, together with special die treatments. He was among the first to introduce beryllium-copper into machine parts. Continually there were growing demands for diverse heat treatments on numerous parts of various products — all involving material and process specifications and inspection procedures. An active member of General Motors' metallurgical committee, he was chairman of several subgroups studying special problems.

Harold A. De Vincentis has accepted a position as metallurgist in the metallurgical development section of the National Advisory Committee for Aeronautics, Cleveland. He was formerly in the metallurgical laboratories, Sylvania Electric Products Inc., Bayside, L. I., N. Y.

Clarence G. Merritt has been appointed chief metallurgist of the research and development division of Olin Industries' Winchester Repeating Arms Co. He was formerly metallurgical engineer in charge of the metallurgical office, Crucible Steel Co. of America, New York.

Robert H. McCreery has recently been promoted to principal metallurgist at International Harvester Co., Evansville, Ind.

Frank B. Cuff, Jr., who received his master's degree from Massachusetts Institute of Technology in June, has been appointed to the metallurgical staff to do research work at the school.

H. C. Bostwick, who has represented the Drever Co., Philadelphia, in Ohio, western Pennsylvania and western New York for the past five years, has recently been appointed district manager of the same territory.

Arthur J. Williamson has been appointed vice-president in charge of manufacturing operations at Tube Reducing Corp., Wallington, N. J. He was formerly with Summerill Tubing Co. as plant manager at the Carnegie, Pa., plant, and as chief metallurgist at the Bridgeport, Pa., plant.

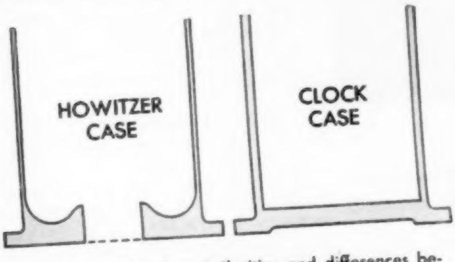
War Baby grows into a Clock Case

During the War, the Worcester Pressed Steel Co. worked out a technique for forming 4.5 howitzer shell cases of cartridge brass. The case was 3¾" high, 4¾" o.d., with thin walls and thick base that included a difficult flange, the material for which had to flow entirely from the base of the cup. The successful solution of the many problems required careful tool design, plus skilled control of each operation.

Later the Chelsea Clock Co. asked Worcester if it could cold-form clock cases out of commercial brass. A study of the clock case revealed striking similarities between it and the howitzer case, but on the other hand there was one important difference. The large radius on the inside of the howitzer case was not permissible in the clock case, because of the space required for the works. It was found that the bottom design could be achieved by squaring the case to the exact height, providing the bottom knockout with exactly the correct amount of spring tension in the restrike, and carefully governing the pressure and speed of press travel. The complete coordination of these factors resulted in a perfect case, and another example of the adaptation of war-learned skills to peace-time products.

• If you have problems in connection with the fabrication of copper and its alloys, or aluminum alloys, remember that the Revere Technical Advisory Service often can be helpful.

Chelsea Ship's Bell Clock, The Vanderbilt model, made by Chelsea Clock Co., Chelsea 50, Mass. Case drawn in one piece out of commercial brass by Worcester Pressed Steel Co., Worcester 6, Mass.



Cross sections showing similarities and differences between the howitzer case and the clock case.

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Personals

Robert W. Mason, Jr., ⊕, has recently joined National Farm Machinery Co-operative, Inc., Shelbyville, Ind., as foundry manager.

A. O. Schaefer ⊕ has been elected vice-president in charge of engineering and manufacturing by the Midvale Co., Philadelphia, rather than vice-president in charge of sales, as reported in the July issue.

Gerard H. Boss ⊕, formerly in the metallurgy division, Oak Ridge National Laboratory, Oak Ridge, Tenn., has recently joined North American Aviation, Inc., Downey, Calif., as a materials engineer in the aerophysics division.

J. J. Schrinner ⊕, formerly metallurgist in the process and materials division, Hotpoint, Inc., Chicago, is now metallurgist in the component and materials testing laboratory, Crosley Division, Arco Manufacturing Corp., Cincinnati, Ohio.

R. K. McKechnie ⊕, formerly metallurgist on the staff at Knolls Atomic Power Laboratory, General Electric Co., Schenectady, has been transferred to the carboloy department as a metallurgist in the vacuum melting division.

Arnold E. Nilsen ⊕ has been employed as a research metallurgist at the titanium division of National Lead Co., Sayreville, N. J., since he graduated from Michigan College of Mining and Technology.

Ferdi B. Stern, Jr., ⊕, is opening a commercial inspection laboratory in Houston, Tex., for the Magnaflux Corp.

R. L. Beck ⊕ has recently been employed in the metallurgical division at Battelle Memorial Institute.

Julius M. Simmons ⊕, formerly manager of technical services, Joslyn Stainless Steels Co., Ft. Wayne, Ind., has taken a position as assistant director of the metallurgy division, Argonne Metals Laboratory, Chicago.

Clyde E. Williams ⊕, director of Battelle Memorial Institute, Columbus, Ohio, has been presented with a doctor of science degree by Ohio State University, in recognition of "his great contribution to science, and through science to industry, of his high concept of citizenship, and of his executive leadership".

Henry W. Arauz ⊕ has recently been promoted to industrial manager, Minneapolis-Honeywell Regulator Co., Columbus, Ohio, office. He was formerly sales engineer in the Detroit branch of Brown Instrument Division of Minneapolis-Honeywell.

Joe S. Yamamoto ⊕ has resigned his position as plant metallurgist at American Foundry & Machine Co., Salt Lake City, and is now plant superintendent and metallurgist for Printers Metal Service & Refining Co., Los Angeles.

Edwin Elliott ⊕, who graduated from Missouri School of Mines and Metallurgy in May, has accepted a position as metallurgist at Eklund Metal Treating Corp., Rockford, Ill.

L. L. Andrus ⊕, formerly vice-president in charge of sales at American Wheelabrator & Equipment Corp., Mishawaka, Ind., has been promoted to vice-president and executive head of the dust and fume division.

Personals

A. F. Davis, director, vice-president and secretary of the Lincoln Electric Co., Cleveland, has been granted the degree of doctor of science by Mt. Union College, Alliance, Ohio.

Emanuel Silkiss, formerly with Inland Steel Co., New York, is now employed as a metallurgist for Wright Aeronautical Corp., Wood-Ridge, N. J.

Thomas E. Eagan has recently been promoted to the newly created position of research metallurgist at Cooper-Bessemer Corp., Mt. Vernon, Ohio. He was formerly laboratory supervisor of the company's foundry research laboratories in Grove City, Pa.

C. R. Horton, Jr., and **D. H. Marlin** have been appointed manager and assistant manager, respectively, of the engineering development department, Dravo Corp.'s Engineering Works Division, Pittsburgh.

I. Melville Stein has been elected to the newly created post of executive vice-president of Leeds & Northrup Co., Philadelphia. He is director of research at the company and has been there since 1919. Prior to that time he was personal assistant to Thomas A. Edison, while he was chairman of the Naval Advisory Board.

William J. Thomas, general sales manager of Babcock and Wilcox Tube Co., Beaver Falls, Pa., has been named to the Tubing Industry Advisory Committee of the Office of Price Stabilization, and to the Welded and Seamless Steel Tubing Industry Advisory Committee of the Iron and Steel Division of the National Production Authority.

Dana W. Smith has been named associate director of the division of metallurgical research for Kaiser Aluminum and Chemical Corp., Spokane, Wash. He has been chief research metallurgist for the company since 1947, and had previously been head of the metal section of Glenn L. Martin's engineering laboratories, assistant chief of Alcoa's metal working research division, and has served on the National Advisory Committee for Aeronautics.

John A. Hill, formerly with Continental Aviation & Engineering Corp., is now chief metallurgist with the Mick Manufacturing Co., Detroit.

Rene D. Wasserman, director of research and president of Eutectic Welding Alloys Corp., Flushing, N. Y., has been appointed to the research committee of the National Association of Manufacturers.

C. B. Williams, superintendent of melting at Massillon Steel Casting Co., Massillon, Ohio, has recently been elected secretary-treasurer of the Electric Metal Makers Guild, Inc., Pittsburgh.

H. A. Schwartz, who was named by the Malleable Founders' Society for his outstanding contribution toward progress and development in the malleable iron industry, has been awarded the 1951 Charles H. McCrea Medal by the National Malleable and Steel Castings Co., Cleveland.

Raymond F. Duff has been appointed sales manager of the Pennsylvania Steel Corp., Detroit. He was formerly chief metallurgist at Ford Motor Co., Mound Road Division.

Russian Metallurgy

(Cont. from p. 80) author was published within one year. It is entitled "Principles of Instruction on the Corrosion and Protection of Metals", and has a general coverage, suitable as a college textbook. Akimov is undeniably a first-rate scientist; either of his books would be instructive and well received if translated.

Although he again presents approximately the same number of illustrations (371), the typography is considerably inferior to that of the advanced text. However, his technical approach is excellent. Consideration is given gaseous corrosion, as well as aqueous chemical and electrochemical. Principal metal and alloy types are covered, and his discussion of stainless steel is one of the best I have yet seen in Russian literature. This, however, still leaves much to be desired. The inference remains that Russia lags well behind America in stainless steel technology.

Molecular Physics

By E. A. Strauf
Govt. Tech.-Theoret. Pub. (Moscow, Leningrad), 576 p. (1949)

Of astonishing breadth of coverage, this text for advanced technical students contains 324 figures (no halftones) and strides through elementary physics, kinetics, mechanics, thermodynamics, atomic physics, crystallography, physics of gases, liquids and solids — also colloid chemistry! The presentation is good, treating the various subjects as thoroughly as most English texts, and along conventional lines.

In the concluding third section, Chapter V (28 p.), he dips into phase diagrams, certain constitutional features of alloys, and a brief treatment of "dislocations" and "holes" in solid lattices — one of the few places that this important phase of solid-state physics has appeared in Russian books coming to this writer's attention. However, Strauf gives the Russian Joffé credit for the discovery of latticular "holes" in 1923, and the Russian Frenkel credit for their explanation. The researches of Joffé on this subject subsequent to 1922 are known to students of imperfection structure, but a question properly arises as to whether he "discovered" the phenomenon, in view of Griffith's work in 1920. A question also arises whether Frenkel — certainly a great scientist — first "explained" them,

(Continued on p. 102)

The original PSC carburizing box, now the most widely used in industry.

Perforated basket, illustrating the strength and light weight of PSC units.

An example of the many special-purpose boxes we design and fabricate.

Retort and ring for gas carburizing furnace; all light gauge welded alloy.

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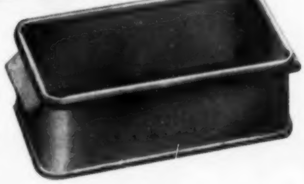
Guarantee of Satisfaction

For years we have been guaranteeing PSC carburizing containers. It is our feeling that this gives more assurance than would claims based on cases where PSC equipment gave remarkably long service. Too many variables are involved. We believe what is most important to the purchaser of heat-treating equipment is the breadth and wealth of the maker's know-how. So may we point out that PSC was a pioneer, and is now the largest manufacturer of carburizing containers. PSC welded alloy heat-treating units are furnished in any size, design or metal specification: annealing and carburizing boxes, fixtures, retorts, covers, etc. Send blue prints or write as to your needs.

A "PSC" designed-for-the-job fixture; this one eliminated three handlings.

Chimney type boxes for carburizing ring gears, furnished in any size.



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Stack type baskets for small lots of different parts in gas furnaces.

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Russian Metallurgy

(Starts on p. 78)

since Darwin in England in 1913 and 1914 provided a theory for mosaic imperfection, and the discussion is not yet closed today.

Although Strauf discusses "dislocations" (using an equivalent Russian word), his attention is brief, and he shows no knowledge of the world-wide investigation of the past two decades, specifically since G. I. Taylor's fruitful work in 1934. He apparently goes no further than the old "Lockerstellen" concept of Smekal a quarter-century back. This indication of limited information is made more striking in Chapter VIII on colloids, gels, and macro-molecules by his neglect of the colloidal and the micellar theories of his own countrymen, von Weimarn and Klyachko.

Despite such hiatuses in contemporary phases of the discipline, the text represents an impressive effort and a splendid classical foundation.

The Blacksmithing Business

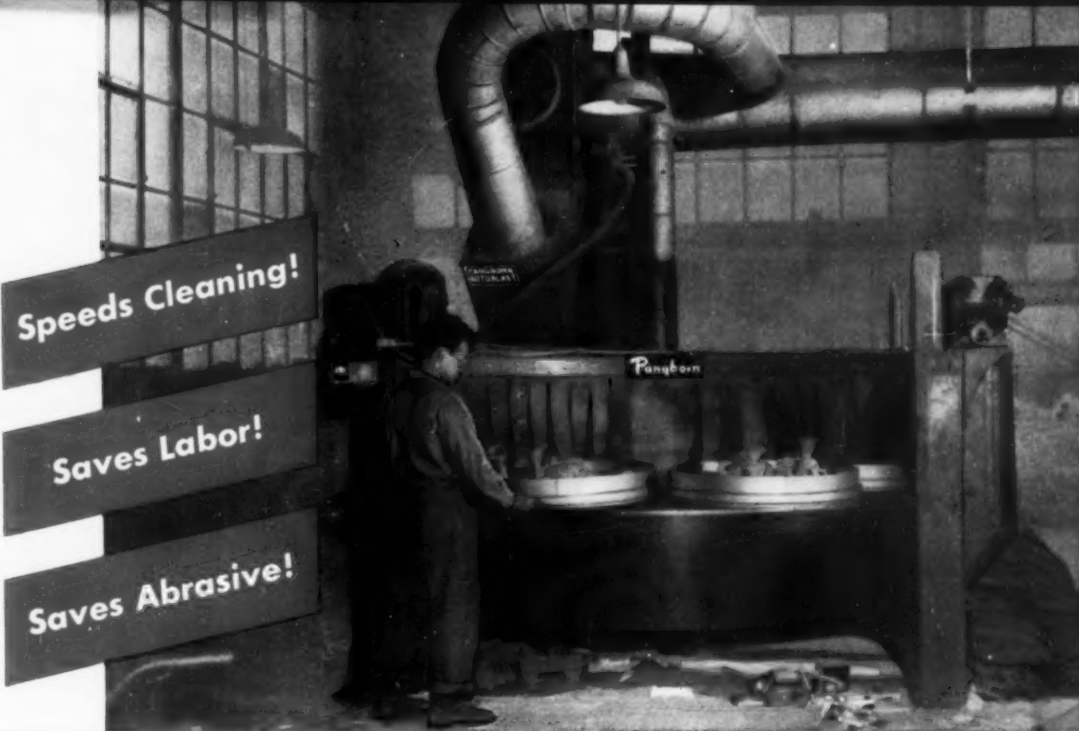
By G. G. Kamenshikov
Govt. Sci.-Tech. Pub. (Moscow), 312 p. (1948)

Issued by the Ministry of Labor Reserves, this book probably carries more information to an American reader between the lines than in the text itself. The opening words of the "Introductory Lesson" are as follows:

"Prior to the Great October Socialistic Revolution [capitalization is his], czarist Russia had a feebly developed mechanical construction industry. A great quantity of various machines and tools was imported from other countries. The czarist government presumed that Russian workers are unable to make complicated machinery. In reality, the trouble did not lie in the Russian workers, but in the fact that the czarist regime itself never wanted the development of a mechanical construction industry. After the October socialistic revolution, the Soviet government decided to convert their backward agricultural country into a country of industry, into a country of the most advanced technics."

The author then proceeds with an outline of the 5-year plan for producing 65,600 heavy trucks, 112,000 tractors, etc., in the period 1946 to 1950. The first question in the listing at the close of the chapter is similarly: "What was the

(Continued on p. 104)



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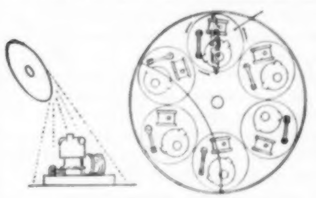

Pangborn "LG" ROTOBLAST Tables too because they're designed for fast, low-cost cleaning of intricate and fragile work. As shown above they clean *completely* because abrasive is hurled at a 45° angle to the work. And *uniform* cleaning is assured because auxiliary tables revolve castings under blast stream.

No matter what you clean, Pangborn has a standard ROTOBLAST Table designed for your job. Included in the standard line are *Turn-Style* Tables for bulky castings . . . and *Table-Rooms* for jobbing work. For full information on the right Pangborn ROTOBLAST Table for your job, write to: PANGBORN CORPORATION, 1800 Pangborn Blvd., Hagerstown, Md.

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BLAST CLEANS CHEAPER

with the right equipment for every job

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Russian Metallurgy

(Starts on p. 78)

attitude of our Country in a technical sense prior to the October revolution, and what did it become under Soviet authority?"

After this ideological grounding, Kamenshikov proceeds to describe the working of metals from a backyard blacksmithing operation on up to the handling of heavy steel-mill equipment. Of 270 illustrations, the first is a hand punch. Figure 103 gives the head construction of the Pt-Pt/Rh immersion thermocouple (for the best American steelmaking practice today!); and the closing chapter advises the reader as to the general demands made by this type of vocation, and the qualifications he should possess if he wishes to enter the field of metalworking.

This brief review should convey the proper impression: That Russia is taking some carefully considered steps in the channeling and utilization of its potential technical personnel — steps which we could well heed. The book is poorly printed, but well conceived — the introductory sales talk on the Soviet notwithstanding.

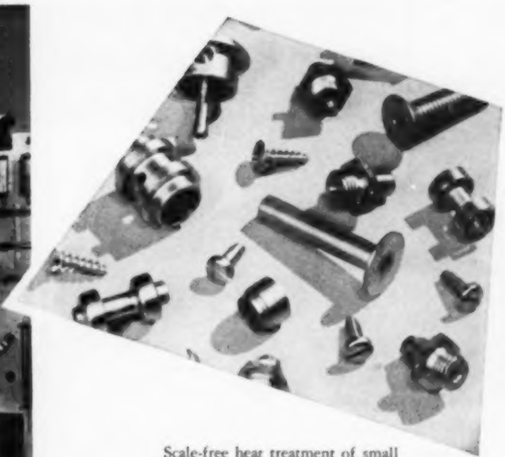
Strength of Materials

By N. M. Belyaev
Govt. Tech.-Theoret. Pub. (Moscow, Leningrad), 6th Ed., 772 p. (1950)

Apparently a standard text in Russian higher technical schools, this book is similar to some of ours in scope and in conventional treatment of the elastic, plastic, and elastic behavior of solids. The author died during World War II and the 6th edition represents a revision by various professors on the staffs of the Leningrad Institute of Railroad Transportation Engineers and the Leningrad Polytechnic Institute. The presentation is precise and mathematical, with a liberal use of diagrams; but, characteristic of Russian publications, the paper is inferior, the format naive, and halftone reproductions are restricted to seven or eight unattractive figures.

Because the English renditions "Belyaev" and "Belaiew" refer to the same Russian name, one's curiosity is at first aroused as to whether the author listed here is a relative of the widely known Col. N. T. Belaiew. The name index in *Chemical Abstracts* lists both Belaiew and Belyaev. Colonel Belaiew apparently derived the spelling "-aiew" because

(Continued on p. 106)



Scale-free heat treatment of small parts in Ferrotherm furnaces depends on gas tight Inconel muffles.

A Ferrotherm furnace, equipped with Inconel muffle, used for bright annealing and hardening of stainless steels and air hardening tool steels.

INCONEL MUFFLES OUTLAST OTHERS 12 TO 1 IN FERROTHERM CO. ATMOSPHERE FURNACES

The Ferrotherm Company of Cleveland, Ohio, and Pittsburgh, Pa., has developed and built a number of unique furnaces for the special treatment of metals. Among the processes carried out in these furnaces are:

—**Bright hardening of hardenable stainless steels and air hardening tool steels.**

—**Furnace brazing of stainless steel and other alloys.**

—**Bright annealing of stainless steel, tool steel and other alloys.**

—**Custom treatments, such as solution and precipitation of various alloys including "Duranickel®", "K"® Monel, Beryllium Nickel, Beryllium Copper, as well as electrical and magnetic steels.**

The atmospheres used for these treatments are anhydrous dissociated ammonia, or pure, dry hydrogen. It is imperative to the success of these treatments that the purity and dryness of furnace atmospheres be maintained throughout the heating cycle. This means, of course, that furnace muffles must be dependably sound and tight at all times.

Mr. John R. Gier, President of the Ferrotherm Company, has this to say about his concern's experience with furnace muffles:

"The engineering requirements for a metal to be used in our furnace muffles are very severe. Chief among them are:

A) Good resistance to cracking caused by the extreme thermal variations inherent in batch type operation.

B) Good resistance to oxidation at temperatures up to 2100° F.

C) Good fabricating qualities; especially good welding characteristics because joints must be tight and gas-leak proof.

"We tested a number of different materials for this application, and Inconel® proved to be the best of all. The fact that we have been using Inconel exclusively for our muffles for the last ten years is the strongest indication I can give of our satisfaction with Inconel on all counts.

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Because current government demands draw so heavily on the available supply of nickel and its alloys, you may not be able to buy all the Inconel you need right now. However, we will continue to report interesting service stories and developments, in the hope that they will be of value to you in the future.

And, of course, you are always welcome to bring your high-temperature metal problems to INCO's Technical Service Section. Write them, outlining your problem. They may be able to suggest a solution.

THE INTERNATIONAL NICKEL COMPANY, INC.
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EMBLEM OF SERVICE INCO

INCONEL . . . for long life at high temperatures

Russian Metallurgy

(Starts on p. 78)

Continental pronunciation of this bisyllable is the equivalent of the Americanized "-yaev". Colonel Belaiew, an expatriate in Paris since World War I, writes, "I am at a loss to say whether he is a relative or not, as people in Soviet Russia are not encouraged to correspond with those who live outside their dominion. This rule is particularly strict in the case of people who have left Russia."

In the two concluding chapters, Belyaev touches on metallurgy for the first time in his book. Chapter 36 describes transverse fissures in rails and axles, but gives no reference to the "flake" or to theories of flaking, whose discussion has occupied world-wide metallurgical attention since early in World War I, and particularly since the identification of the role of hydrogen by German investigators in 1935. His closing Chapter 37 similarly dates his metallurgical training because of a few simple sketches of slip bands and a dismal discussion of theories for the strength of metals entirely involved in the decades-old argument over normal stress versus shear stress as the determining factor for failure. None of the past 30 years' contributions on the nature of the solid state illuminates any part of the book. Perhaps this is not essential for a conventional textbook on strength of materials; but any progressive-minded author would certainly want to expose his readers at least to the germinal aspects of modern thought in such highly pertinent theoretical fields.

Pavlov's Works

First published in 1924, and now in its 3rd edition, is a book by the "grand old man" of the Russian blast-furnace industry. M. A. Pavlov — holder of a name perhaps even more famous in other branches of science — writes about "The Metallurgy of Pig Iron" from a background of more than half a century.

In this first volume on "Raw Materials" he restricts his attention to blast furnace design and operation, a discussion of raw materials, and a comprehensive account of the industry in Russia, Germany, England, Sweden, and the United States. His references run more than a hundred, drawn copiously from the literature of the various countries.

(Continued on p. 108)


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ARC WELDING ELECTRODES
No Finer Electrodes Made Anywhere

Russian Metallurgy

(Starts on p. 78)

Important to note is that the common translation of the Russian *choo-goon* (phonetic) in this country has often been "cast iron", whereas this is in error. The Russian metallurgist groups all of the high-carbon irons under the one name,* and Pavlov's attention is here specifically on the blast furnace. Cast iron finds only brief mention as a subordinate range of pig-iron compositions. The point is made because notices on Pavlov's book have been seen under the title: "Metallurgy of Cast Iron", which is entirely in error. Also, in the way of translation difficulties, it is surprising to find the Russian phonetic translation of our "cementation" referring to "electroplating" — not carburizing. This has led to numerous misinterpretations to be found in the literature and in technical Russian-English dictionaries.

Pavlov's second volume on "The Blast Furnace Process" is in its 6th edition, printed under government auspices, rather than the Academy of Sciences, and is intended for advanced metallurgical students. An idea of the thoroughness of the text will be gained from the fact that Chapter 2, on physico-chemical processes of reduction of iron ore, covers nearly 300 pages and alone has a bibliography of 179 references. The rest of the book with similar thoroughness treats gas analyses, coke balance, charge calculations, and so on.

As has been remarked above, M. A. Pavlov is Russia's "grand old man" in metallurgy, having more than half a century of experience with the blast furnace and sixty-some years of general ferrous metallurgy behind the writing of his "Reminiscences of a Metallurgist", Govt. Sci.-Tech. Pub. (Moscow), 292 p. (1945). Both the background of the man and the conversational style of the book remind one of Sauveur's "Metallurgical Reminiscences" (1938) or of Brearley's "Talks on Steelmaking" (1946).

Because Pavlov is truly only reminiscing here, the text is not instructive metallurgically except in

(Continued on p. 110)

*According to Oushakov's "Explanatory Dictionary of the Russian Language" — probably the most authoritative publication on the Russian language — *choo-goon* is ". . . iron, containing certain proportions of carbon, derived from the smelting of iron ores in the blast furnace and being more brittle and less forgeable than steel" — that is to say, pig iron.

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Russian Metallurgy

(Starts on p. 78)

a historical sense. His visit to America a half-century ago to study blast furnace practice is described in an entertaining way — certain to give nostalgic pleasure to any old-timer who remembers names such as Edgar Cook, Harry Hughes Campbell, John Fritz, Frank Roberts, Andrew Carnegie; also the early days at Lackawanna, Scranton, Steelton, Bethlehem, Duquesne Works, Edgar Thompson Works, the Andover Furnace at Phillipsburg, and the world-renowned blast furnaces "Lucy", "Elisa", and "Isabella", whose names particularly tickled Pavlov.

Those were the days when European furnaces scarcely exceeded 100-ton capacity; in America the Edgar Thompson Works was building its first 400-tonners. Pavlov goes into special detail on his encounter with the great secrecy blanketing all operations here. Much of the occult side was disclosed to him on one occasion, and he was even shown the "Lucy"; but a pledge was then exacted to keep the information to himself.

Those were also the days, as Pavlov notes, when the American Plan in New York hotels cost $4 per day, and in lesser cities only $2.50!

The Heat Treatment of Steel

By I. E. Kontorovich
Govt. Sci-Tech. Pub. (Moscow),
452 p. (1945)

An outstanding text in technical content, though typographically pathetic, this is the Russian equivalent of American books by Sauveur, or Bullens. The coverage is methodical, comprehensive, and of at least the technical depth of the American books, giving a good coverage even of ternary alloy steels and their complex constitutional diagrams, as well as a thorough elementary story of thermal effects in general.

For the iron-carbon diagram, the American standard is reproduced from October 1943 *Metal Progress*, as is a chart of heat treating microstructures from the March 1935 issue. There is a tip-in folder of the A.S.T.M. grain-size chart, and a tip-in of an S-curve by Davenport and Bain measures two feet in height when opened!

While this book proves that capable metallurgical instruction is available in Russia, it contains little if any information not to be found

(Continued on p. 112)

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VERTICAL FURNACES

Saves Time · Reduces Cost

Outstanding
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- A Uniformly annealed strip from edge to edge and end to end of coil
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- E Users of Continuous Annealed Strip report longer die and shear life

Drever Company has pioneered this striking improvement in Continuous Annealing Furnaces for Tin Plate Strip, Silicon Strip, Blue Plate and other strip products. We predict all major steel mills will anneal by this method. Why don't you do it now?

Equipment can be specified for output up to 30 tons per hour of 30" wide x .010" thick low carbon steel. Several sizes are available, in any width.

Furnace illustrated produces Tin Plate and Blue Plate. The shift-over from the Bright Surface required for Tin Plate to the uniformly applied, accurately controlled tight oxide coating required for blue plate is rapidly and easily made.

Installations backed by staff of Engineers and Metallurgists of sixteen years experience in Continuous Annealing of Low Carbon Strip.

Outstanding
DESIGN

1 Speeds up to 1000 feet per minute
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4 Regulated Cooling Rate
5 Predictable Strip Temper
6 Cleaning in same line
7 Low Maintenance
8 Reduction in Floor Space
9 Reduction in Coil Inventory
10 Saving in Overall Annealing and Cleaning Costs

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790 E. VENANGO ST.,
PHILADELPHIA 34, PENNA.

Russian Metallurgy

(Starts on p. 78)

in extra-Russian literature. The great proportion of the bibliography is extra-Russian, representing a rather competent survey of international literature.

On the other hand, many of the Russian authors exhibit an annoying habit [not restricted to Russians!] of publishing material without designating its prior publications. A case in point is Kontorovich's Fig. 363, particularly irking to the present reviewer because it is taken from his own work! The personal affront probably prompts this closing remark that Kontorovich's discussion of flakes in steel is one of the most antiquated portions of his book. This, however, is almost certainly due to the fact that Russia was cut off from the occidental technical press during the 1940-1945 wartime period when the principal advances in "flakology" were being made.

Ferrous Alloys
Vol. I; Iron-Chromium-Aluminum Alloys

By E. E. Kornilov
Acad. Sci. U.S.S.R. (Moscow, Leningrad), 132 p. (1945)

With 210 references and 154 figures, including a surprising number of halftones, this book is one of Russia's best contributions to physical metallurgy, and a compilation on heat resisting alloys which would be a welcome sight in the English literature.

While it is often difficult, as remarked immediately above, to distinguish between original Russian work and unacknowledged rescripts from extra-Russian sources, certainly much of the material in this book cannot be found elsewhere. The photomicrographs and the photographs must be original, and several areas in his treatment extend clearly beyond anything to be found in either German or English texts. Jänecke, for example, in the 1949 edition of his "Handbuch aller Legierungen" devotes ten lines to the Fe-Cr-Al system, cites one reference, and closes with the statement that "a constitutional diagram for the alloy system is not known". Houdremont also gives but little attention to this system in the 1943 edition of his encyclopedic "Handbuch der Sonderstahlkunde"; although Hessenbruch's 1940 "Metalle und Legierungen für hohe Tem-

(Continued on p. 114)

Russian Metallurgy

(Starts on p. 78)

peraturen" carries two pages of discussion with a schematic diagram showing the two Fe-Al and Fe-Cr binary diagrams, with an indicated ternary section for 0° C. America's 1950 edition of "Metals at High Temperatures" by F. H. Clark gives little or nothing on the system, nor does the 1948 "Metals Handbook" of A.S.M.

By way of marked contrast, the entire 192 pages of Kornilov's text deal with this system. Binary and ternary diagrams are profuse, and the latter are often outstanding. An excellent solid model for the Fe-Cr-Al system is photographed from three sides, and other three-dimensional studies display characteristics of constitution, resistivity, impact strength, density, and other properties. Oxidation data are voluminous, and a section even deals with the effects of further additions of carbon and titanium. The latter element, incidentally, showed the important effect of eliminating transcrystallinity — a markedly weakening characteristic of cast alloys of this sort. Those who wish to go further into this matter and cannot use the Russian original may turn to the six-page review under the title "Russians Have New Heat Resistant Alloys" in *The Iron Age* for March 22, 1951, written by S. L. Case. Commercially useful alloys are found in the region of 22% Cr, 5% Al (ductile alloys heat resistant up to about 2275° F.; 40% Cr, 8% Al, ductile when hot and heat resistant up to about 2450° F.; and 60% Cr, 10% Al castings (brittle hot or cold), heat resistant up to about 2725° F.

Alloys of Magnesium With Aluminum and Zinc

By V. I. MIKAEVA
Acad. Sci. (U.S.S.R.) (Moscow, Leningrad), 195 p. (1946)

One of the few Russian texts printed on a good grade of paper, this monograph on the Al-Mg-Zn system would appear to be required reading for anyone in this field. There are 82 figures — principally constitutional diagrams and their sections — in addition to 42 photomicrographs. Thirteen tables of experimental data cover 50 pages of text. The bibliography contains 77 references, including all work by German, English and American

(Continued on p. 116)

A REGULAR SERVICE OF THE **COOPER ALLOY** FOUNDRY CO., HILLSIDE, N. J.

Technical Topics

MACHINING 18-8 STAINLESS STEEL—METALLURGICAL CONSIDERATIONS

Norman S. Mott
Chief Chemist and Metallurgist

Most of the headaches associated with the machining of stainless alloys can be cured with machining experience, but some of them are associated with metallurgical considerations. This applies both to the wrought and the cast materials. Too often the underlying causes and the possibilities for their correction are not well understood. The purpose of this discussion is to review these causes, and to indicate the steps which may be taken to eliminate them.

The basic difficulties experienced in machining of stainless alloys are:

1. The metal is too hard . . . The cutting tool cannot penetrate or too much tool pressure is required.
2. The metal is too tough . . . It tears away instead of breaking up into chips.
3. Frictional or galling characteristics are excessive . . . Chips adhere to the tool tip, resulting in the balling up of the cut metal.
4. Microstructural non-uniformity or segregation . . . This causes hard spots and results in rough or uneven machined surfaces.
5. The metal work hardens . . . This results in a blunt tool and a polishing rather than a cutting action. Let us review each of these difficulties in turn:

Hardness: Hardness in 18-8 stainless, such as to cause difficult machining, is not an inherent characteristic. It is usually found in the form of work hardening, either from cold rolling or from hot working to too low a temperature. Although machining operations have been conducted up to as high as 350 Brinell, this requires a slow special technique and for practical purposes such hard metal should be soft annealed by water quenching from 1950–2100°F.

Toughness: Correctly heat treated 18-8 stainless in the condition for maximum corrosion resistance is very tough and ductile. These are desirable characteristics from a mechanical viewpoint, but they are pretty tough on machinability. Experience has shown that machining difficulties can be minimized through the addition of an embrittling agent such as selenium, sulphur or phosphorus. And when properly controlled, maximum machinability with a minimum loss of corrosion resistance can be accomplished.

Galling: Galling tendencies, which are associated with softness and ductility, are also largely eliminated by controlled additions of various alloying elements.

Hard Spots: Hard spots are caused by microstructural segregations such as carbides and other hard phases. The machining tool in passing over these areas does not cut properly and gives a raised and usually a glazed surface, producing a so-called "orange peel" effect. Correct quench annealing heat treatment is required in order to eliminate such a condition. Another cause of hard spots may be burnt-in pieces of molding sand, a condition sometimes found in poor quality castings.

Work Hardening: Work hardening is a universal characteristic of the 18-8 stainless steels. Pressure by the machine tool tends to cold work the surface and make it hard. To offset this, there are a number of machinists' tricks which are somewhat beyond the scope of this discussion. (Further data on the machining techniques can be found in J. J. Roberts' paper, "Don't Fear Threading of Stainless".)

Russian Metallurgy

(Starts on p. 78)

investigators listed in ⊕ Metals Handbook and in Hanbuch aller Legierungen, as well as Japanese and Russian studies. As a result, the phase boundaries are importantly modified in a number of respects from those now popularly deriving from Köster's work in Germany, and reproduced in both handbooks just mentioned.

Studies on the Machining of Metals

By N. I. Reznikov
Govt. Sci-Tech. Pub. (Moscow), 587 p. (1947)

Published under the auspices of the Soviet government as a part of a program for technical literature in the field of mechanical engineering, this text is of surprising proportions with its 587 pages, 350 figures, numerous tabulations, and highly mathematical treatments (there being more than 600 numbered equations given).

While this reviewer is not qualified to judge a text dealing primarily with mechanical rather than metallurgical aspects of machining, Reznikov's book is obviously of high caliber and filled with information that would interest any American

scientist in the field of machining. Unlike many of the Russian publications which feast upon material in the international press, Reznikov's text begins at the other and also well-known extreme with a description of how the science of machining really first began with Professor Tima in Russia (!) about 1868, and it then continues to derive its principal support from Russian work. The majority of his 200 references concerns citations from Russian literature. ⊕

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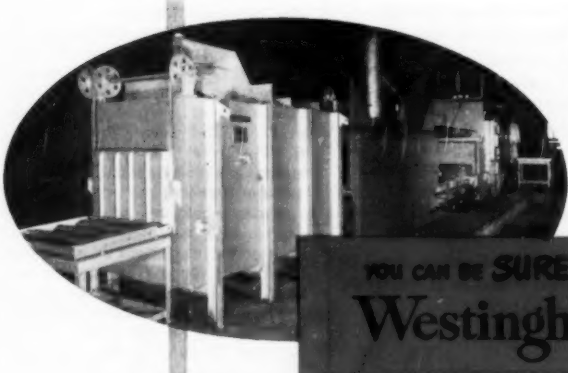

IF YOUR PRODUCT CALLS FOR HEAT-TREATING ... IT CALLS FOR A WESTINGHOUSE FURNACE ... GAS OR ELECTRIC

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Westinghouse

HEAT-TREATING FURNACES

Hard Metals by Impregnation*

THE CONVENTIONAL method of preparing cemented carbides by mixing the carbide and the binder metal powder, compacting the mixture and sintering was patented by Schröter in 1923. A year before, Baumhauer had suggested that cemented carbides be produced by infiltrating carbide skeletons with liquid binder metal. This earlier suggestion was soon forgotten, because Schröter's method proved superior. The authors of this paper present a re-examination of the infiltration method for making carbides.

Two types of products were investigated. The first type included those compositions which are conventionally used for cutting tools. The second type consisted of pure titanium carbide, and titanium carbide with additions of molybdenum carbide which were impregnated with nickel-chromium, cobalt-chromium and cobalt-chromium-molybdenum alloys. These compositions are of interest because of their high strength and oxidation resistance at elevated temperatures.

In the case of the carbide compositions for cutting tools the infiltrated products could be compared directly with conventionally produced cemented carbides of the following compositions:

94% WC	6% Co	
90% WC	10% Co	
95% WC	15% Co	
17% TiC	6% Co	bal. WC
15% TiC	8% Co	bal. WC
5% TiC	8% Co	bal. WC

The infiltrated products were prepared by pressing the carbide powder (a prealloyed carbide powder was used with the composition containing the titanium carbide) at pressures of 11,000, 28,000 or 56,000 psi. into rectangular shapes approximately 2 in. x 1 in. x ⅜ in. The compacts were presintered for 1 hr. at 950° F. and given a final sintering for 1½ hr. at 1500° F. Both treatments took place in a high-frequency vacuum furnace.

Pure cobalt or cobalt to which up to 40% tungsten carbide had been added were used as infiltrants. The reason for adding tungsten carbide to the infiltrant cobalt was to avoid, as much as possible, an attack of the cobalt on the surface of the compact. This attack may produce

(Continued on p. 120)

*Abstract of "The Preparation of Cemented Carbides by Infiltration", by R. Kieffer and F. Kölbl, *Berg- und hüttenmännische Monatshefte*, Vol. 95, March 1950, p. 49-58.

Hard Metals by Impregnation

(*Continued from p. 118*)

holes up to $\frac{3}{16}$ in. deep where the liquid metal first penetrates into the carbide skeleton. On the other hand, with too much carbide in the infiltrant, an excess was deposited on the surface of the compact. The infiltrant powder was also pressed into compacts and sintered in a high-frequency vacuum furnace between 1150 and 1200° C.

The carbide skeletons were infiltrated by placing sufficient infiltrant compacts (so that the final product would have the desired composition) upon the skeleton compacts, and heating them in a high-frequency furnace for 1½ hr. at temperatures between 1380 and 1460° C., depending upon the cobalt content. The infiltrated carbides showed porosity gradients from the side where the infiltrant entered the skeleton which was low in porosity, to the side away from the infiltrant which was higher in porosity. A high-temperature sintering treatment subsequent to infiltration improved the density distribution somewhat.

The infiltrated carbides were compared with conventionally prepared carbides as to hardness and to wear resistance in an actual machining test. The infiltrated carbides with 6% cobalt had a hardness 2 points lower on the Rockwell A scale and wore approximately 3 times as fast as conventionally prepared carbides. The material with 15% cobalt had the same hardness as conventional material, but was not tested for wear. The steel cutting grade with 5% titanium carbide and 8% cobalt wore only about 50% faster when made by impregnation instead of conventional sintering. A possible advantage of the infiltrated carbides is their higher toughness which may be due to the absence of internal stresses.

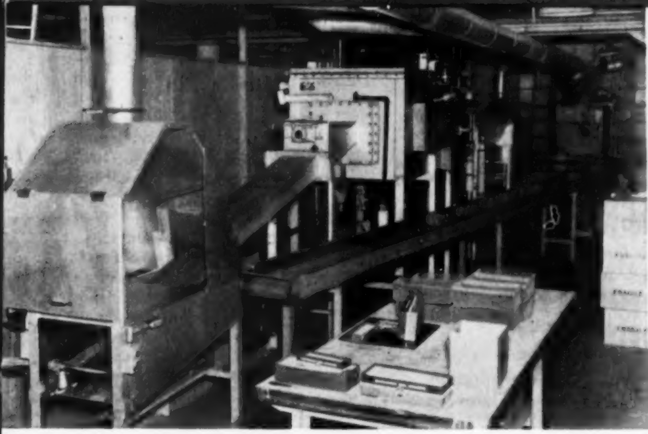
Three groups of experiments were made on infiltrated titanium-base carbide:

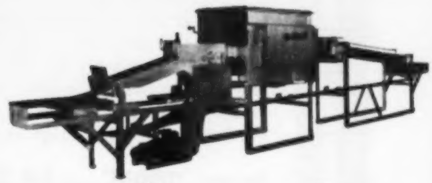
1. Pure titanium carbide skeletons, sintered in vacuum at 1400° F., were infiltrated with an 80% nickel, 20% chromium alloy on both sides of the skeleton compact. The infiltrated compact contained 6.1% chromium, 24.6% nickel, was practically pore free, very tough, and had a hardness of Rockwell A-83 to 85.

2. Skeletons were made from previously alloyed mixtures of titanium carbide and molybdenum carbide with from 3 to 50% molyb-

(*Continued on p. 122*)

At various RCA plants 26 "CERTAIN CURTAIN" Furnaces





Famed "humpback" design

For its critical controlled-atmosphere heat treating, RCA makes wide use of the inclined-hood furnace developed by C. I. Hayes, Inc., out of its experience as the oldest maker of electric atmosphere furnaces. Shown at left is an installation at the Harrison, N. J., RCA plant.

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"Humpback" saves better than 90% of atmosphere cost

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Hard Metals by Impregnation

(Continued from p. 120)

denum carbide by sintering 2 hr. at 1500° C. in hydrogen in a carbon-resistor furnace. These skeletons were infiltrated with the same proportion of an 80% nickel, 20% chromium alloy as the first group in a vacuum at temperatures between 1550 and 1400° C. The hardness of the infiltrated carbides increased from 85 to 87 Rockwell A with increasing molybdenum carbide content, but the toughness decreased.

3. Skeletons of pure titanium carbide and of prealloyed carbide mixtures containing 3 and 5% molybdenum carbide were infiltrated with up to 45% of an 80% cobalt, 20% chromium alloy, a 66% cobalt, 28% chromium, 6% molybdenum alloy, and a 65% cobalt, 28% chromium, 6% molybdenum, 1% carbon alloy. Carbides infiltrated with cobalt-base alloys were harder than the ones infiltrated with the chromium-nickel alloy, having a maximum hardness of over 91 Rockwell A for a carbide containing 5% molybdenum carbide in the skeleton and infiltrated with 30% of the cobalt-chromium-molybdenum-carbon alloy. In general, the toughness decreased with increasing hardness.

Only performance tests made of the infiltrated titanium-base alloys were qualitative oxidation tests at 1100, 1200 and 1300° C., in which the thickness and the adherence of the oxide layer was observed. It was found that additions of more than 5% molybdenum carbide to the skeleton mixture decrease the oxidation resistance appreciably. Titanium carbide infiltrated with a cobalt-base alloy stood up somewhat better than when infiltrated with 80% nickel, 20% chromium.

The investigators state that even the best infiltrated material was somewhat inferior in oxidation resistance to an 80% nickel, 20% chromium alloy which was used as a comparison material. The principal advantage of infiltrated titanium carbide-base carbides over conventionally prepared carbides is that the infiltration method permits the preparation of materials containing as much as 60 to 70% binder metal, while the pressing and sintering method does not produce a pore-free material if the binder metal content is above 25%. It is suggested that these heat and scale-resistant infiltrated hard metals may find use in turbine blades.

F. V. Lenel

handles *Boiling HCl* for 2½ years!

This HASTELLOY Alloy Condenser is still on the job in 1-10% Acid Solution

The 28 in. tubes in this condenser for the distillation of hydrochloric acid are made from ½-in. diameter, 16-gage welded tubing of HASTELLOY alloy B. The end disks, which are ⅜ in. thick by 7 in. in diameter, are also of the nickel-base alloy.

For complete information, write for the 40-page booklet, "HASTELLOY High-Strength, Nickel-Base, Corrosion-Resistant Alloys." It contains data on the properties, available forms, and fabricating techniques for all three grades of HASTELLOY alloy.

This condenser, made of HASTELLOY alloy B, shows no signs of corrosion after two and one-half years in a vacuum still for the distillation of hydrochloric acid. Since it was installed, the unit has been in operation two to three days a week, eight hours a day, handling a dilute solution of the corrosive acid at temperatures up to the boiling point.

HASTELLOY alloy B is one of the few commercially available materials that can handle boiling hydrochloric acid—one of the most severely corrosive agents known to the chemical industry. Alloy B is available in all standard wrought forms and can be fabricated by most common methods. Two additional HASTELLOY alloys, designated as C and D, are also available for handling other highly corrosive chemicals, such as sulphuric acid and certain strong oxidizing agents, like ferric chloride and wet chlorine.

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Effect of Air Temperature on Heat Time*

THAT air temperature is a principal determiner of heat time is the conclusion drawn from a study of charge to tap time of 200-ton furnaces making low-carbon heats (0.06 to 0.20% C) in four shops. Points for pitch heats, although somewhat faster than those for oil heats, fall within the same general band of variation. At an average air temperature of 2400° F., the charge to tap time lies within the range 6.5 to 8.75 hr., with the average at about 7.6 hr.; for air temperature down to 2000° F., the increase in average heat time is about 0.75 hr. per 100 degrees decrease in air temperature.

The main sources of improved performance from higher flame temperature are either in the use of combustion oxygen or higher preheat of the combustion air. The improvement accompanying the use of combustion oxygen has been discussed previously by J. S. Marsh (*Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 176, 1948, p. 78-91). The present paper is devoted to a description of the means used for measuring air temperature and of the effect of air temperature on heat time.

Air temperature is measured through a hole in the uptake wall on the pit side just above floor level, using a specially designed velocity couple. The general scheme consists of flowing the hot air at high velocity over the hot junction of the thermocouple by means of an aspirator. The thermocouple, protected from radiation by 5 nickel shields, is located 3 in. from the intake. This location is equivalent to a solid angle of 0.7% of the radiating area.

Suitable gas velocity was established by operating at a series of gage vacua. Operation of the aspirator was standardized at a vacuum of 3 in., which results in air velocity equivalent to several hundred miles per hour.

The absolute accuracy of the temperature measurement is unknown because there is no primary standard of comparison for gas temperature. Readings obtained by the

(Continued on p. 126)

*Abstract of "Significance of Air Temperature in Open Hearth Operation", by John S. Marsh, a paper read before the General Meeting of American Iron and Steel Institute, New York, May 23-24, 1951.


Streamline Your Furnace Line
with the
LOFTUS LINE


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Effect of Air Temperature

(Continued from p. 124)

sodium-line-reversal method under actual openhearth uptake conditions measured by Keith Rumbel of the M.I.T. Practice School, Lackawanna, New York, scattered about both sides of those taken simultaneously with the velocity couple in a way that suggests that the velocity couple reads true gas temperature.

Data have been collected on about 75 heats made in about 40 furnaces in various shops. The average of the air temperatures 5 min. after reversal from the end of the lime-boil to tap is used as a standard comparison. Air temperatures may be cooler or hotter by several hundred degrees than the checkers; this indicates the importance of other parts of the regenerative system such as the fantails, slag pockets and uptake walls.

For a given furnace and fuel input, performance is governed principally by air leakage. Air temperature is more reliable than other conventional indications of infiltration. Instances are cited of increased air temperature and faster heats following reslurrying slow furnaces with low air temperatures that passed routine infiltration inspection. The short-term effect of ore or hot metal addition is to increase the air temperature by increasing the furnace pressure and thereby decreasing infiltration.

In addition to air temperature, potential improvement in openhearth performance depends upon better: *(a)* utilization of fuel, *(b)* refractories, and *(c)* furnace design.

F. G. Norris

Metallurgical Factors in Drill Collars*

In size and analysis, gun tubes are similar to drill collars and the "know-how" with respect to gun tubes can be with benefit transferred to drill collars. As a rule, failures occur by progressive fracture near the last full thread at the shoulder. The pin usually fails; less commonly the crack starts in the box and travels to the outside. The steels used are the 4100, 3100, 8600,

(Continued on p. 128)

*Abstract of "Metallurgical Factors Affecting Drill Collar Performance", by R. J. Stoup, a paper presented before the Division of Production, American Petroleum Institute, Amarillo, Tex., March 1951.

Metallurgical Factors in Drill Collars

(Continued from p. 126)

8700 and 9800 series, with 4100 of proper carbon content the most common. Big-end-up, hot-top molds are to be preferred. Precautions during cooling to prevent flakes are necessary. The methods of working to shape are forging, rolling, or piercing and rolling.

It is suggested that practices with relation to gun tubes indicate that forging has been overestimated from the quality standpoint, and that rolling into solid rounds followed by cold boring or piercing and rolling into a tube will produce a product of satisfactory properties.

The requirements for mechanical properties are approximately 110,000 psi. yield, 140,000 psi. tensile and 280 Brinell. These properties are required for thread strength. The location at which these properties are desired is approximately 1½ in. below the surface.

H-steels should be specified and inspection procedures should be established so that surface hardness can be related to hardness at 1½ in. below surfaces. Effective heat treatment by rapid cooling during the quench is essential to develop high mechanical properties. A water quenching procedure using high agitation to produce uniform cooling is described. While quenching the collar after boring is desirable, solid rounds can be satisfactorily treated prior to cold boring. Distortion and cracking are minimized by quenching in the bored state. Satisfactory properties with relation to straightness are produced by stress relieving after mechanical straightening.

The relation of Izod impact properties to repeated stresses is discussed and it is pointed out that endurance limit and impact strength are not related. It is stated that while the direct relation of impact properties and ability to withstand working stresses is doubtful, there may be some merit in its ability to indicate the success of the heat treatment applied.

The author concludes that the requisite conditions are met in drill collar heat treating by hardening the collar to the correct depth by using proper quenching procedure and sufficient alloy in the steel. Good depth of hardening is obtained with less alloy if the drill collars are quenched in the bored or pierced condition and the water is well agitated. G. W. WHITNEY

Beta-Ray Thickness Gages*

CONTINUOUS gaging of strip in cold mills by contacting micrometers has been in use for a long time, but increases in mill speed have placed them in the class of hot mills, where noncontacting gages are necessary. The latter depend on X-rays (first applied in 1947 and now numbering about 109 in service) and beta rays (experimentally used since 1949).

Both the X-ray and beta-ray gages use radiation energy directed toward one side of the strip. The source of energy is either an X-ray tube or one of a number of radioactive isotopes (Sr^{90} or Ru^{106} is usual). Some of the radiant energy is absorbed by the strip, and the portion that passes through and impinges on a detector is a measure of the strip thickness.

The pick-up unit contains a screen which fluoresces under the action of the X-rays. A sensitive photo-electric cell converts the fluorescent light to an electrical signal which is fed to a suitable amplifier circuit. The amplifier is housed in a cabinet which can, if desired, be a considerable distance away. The output of these circuits is registered by an indicator calibrated in terms of strip thickness.

All manufacturers of X-ray gages claim accuracies of 2% or better. Micrometer checks on all circuits have confirmed this claim. The value of high gage accuracy is limited by the accuracy to which mill controls and strip shape can be controlled.

Reduction of down-time (outages) usually needs attention more than accuracy. Outage seems to depend largely on the electronic talent available in the plant, the accessibility of the instrument location, the spares available, and the preventive maintenance exercised.

In Republic Steel Corp.'s 98-in. hot mill, off-gage rejections for five months preceding installation of X-ray thickness gage was 2.09%; in the succeeding five months it was 1.24%. Cold rolled strip off-gage rejections were 1.91% prior to installation and 1.64% after.

The beta-ray gage is similar to the X-ray gage in many respects, but has two important basic differ-

(Continued on p. 132)

*Extract from "Noncontacting Thickness Gages for Flat Rolled Steel Products", by W. A. Black, paper read before American Iron and Steel Institute, May 1951.

Beta-Ray Thickness Gages

(Continued from p. 130)

ences. In the first place, the radiant energy is beta rays instead of X-rays and, secondly, its source is a radioactive isotope instead of an X-ray tube. It is an excellent example of the industrial application of the by-products of our atomic energy development. While the use of an isotope simplifies the circuit, it also creates new problems requiring special attention. Among these are the ever-present radiation, deterioration of the isotope, low penetration, and wide scatter of the beam.

Circuits used include a beta-ray source, pick-up or ionization chamber, an output amplifier, and an indicator reading deviations from nominal thickness.

Before the instrument is put into service, a dial adjustment brings the indicator to zero for the desired strip thickness. Another dial selects the sensitivity required for the thickness and analysis being measured. These two settings are predetermined by calibration. A third dial is used to compensate for reduction in radioactivity of the source. This decay takes place in all radioactive materials at widely varying rates. Even though it may be slow, it is necessary to compensate for it. This is done by a dial in the standardizing circuit.

In production, the operator merely sets the reference voltage and the sensitivity control dials to figures shown on the calibration curves. The instrument will then read deviation from the desired thickness.

The range of the beta-ray gage is only a fraction of that of the X-ray gage. Its maximum is 0.050 in. The reason for this is the low penetrating power of rays. The operating gap is also small because the rays fan out in all directions from the source.

Accuracy, however, has been maintained within 1%. Outages in production use are negligible.

Safety — The principal precaution is to avoid getting any part of the body in the direct beam. The radioactive isotope is heavily encased in a lead receptacle, except for a small opening through which the measuring rays pass. When the instrument is out of service, a lead

(Continued on p. 134)

INTERNATIONAL HARVESTER

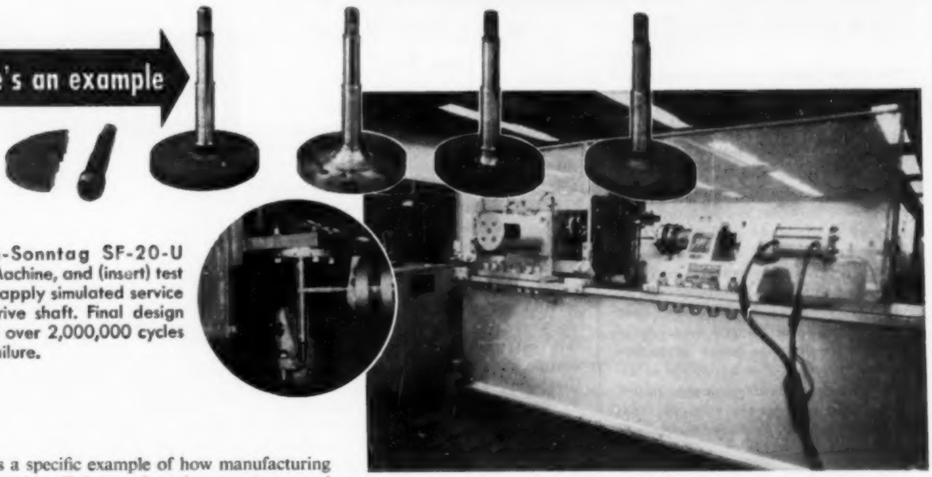
satisfies its "Organized Curiosity" with the aid of

BALDWIN equipment

Progressive management's recognition of the importance of testing and research in keeping its products ahead is dramatically illustrated by International Harvester Company's Manufacturing Research program. Established at a cost of $4,000,000 and recently expanded with an additional $1,000,000 investment, the Manufacturing Research Laboratories permit the scientific study of parts and materials with a minimum of time and effort.

J. W. Armour, Manager, says, "Research is nothing but organized curiosity . . . and Manufacturing Research is nothing but an organized inquiry into the facts of our industrial life." Baldwin Testing Equipment plays an important part in implementing the varied activities.

Here's an example



Baldwin-Sonntag SF-20-U Fatigue Machine, and (insert) test set-up to apply simulated service test to drive shaft. Final design withstood over 2,000,000 cycles before failure.

Here is a specific example of how manufacturing research paid off in product improvement—and production savings.

The drive shaft illustrated above drives a working mechanism. It consists of a flange or head plate welded to a step-type shaft. Field failures occurred when shafts twisted off at the key-way. A switch to alloy steel, plus heat treatment to improve physicals, eliminated this weakness . . . but failures occurred at the center of the weld metal. Next projected step called for an increase in size of shaft—which would involve major design changes, increased machining and added material. The problem was then turned over to Manufacturing Research.

Loads were applied to various specimens, and stress concentrations plotted. Test pieces are shown above. Final design withstood over 2,000,000 cycles. Problem solved without adding extra material, or altering other machine components.

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In Canada: Peacock Bros., Ltd., Montreal, Quebec

Beta-Ray Thickness Gages

(Continued from p. 132)

shutter is automatically closed. Since beta rays tend to scatter into the surrounding area, it is desirable to attach shields to the gaging head. They can be steel plates of a size and spacing that will make the beam inaccessible to even a finger. These shields also guide the strip into the gap, thus adding a functional service.

In order to acquire one of these instruments, the user must agree to abide by rules of the Atomic Energy Commission. The isotope itself does not become the property of the purchaser of the instrument. It remains the property of the instrument manufacturer who is responsible to the Atomic Energy Commission for the safe handling and disposition of all radioactive materials he acquires.

Fluidized Solids Technique for the Reduction of Iron Ore*

This paper makes available data from a series of experiments carried on a few years ago to determine whether the fluidizing technique offered a practical method for direct reduction of iron oxides to produce suitable melting stock.

A representative variety of iron oxides was studied and, in spite of some limitations in the experimental equipment used, the data show that it is very difficult to obtain satisfactory fluidizing of commonly used iron oxide ores so that they may be satisfactorily reduced to metallic iron in a reasonable time. The study included treatment and concentration of the products obtained to determine whether the iron content could be increased to an acceptable level after reduction in the fluidization process. This expedient did not prove practical either.

The data in the paper are a valuable addition to information in the literature regarding the possible use of fluidization techniques, which are quite useful in many other industries, in the direct reduction of fine iron ores.

P. E. Cavanagh

*Abstract of "Direct Reduction of Iron Ore Using the Fluidized Solids Technique", by M. Tenenbaum and C. M. Squarcy, presented before General Meeting of American Iron and Steel Institute, at New York, May 1951.

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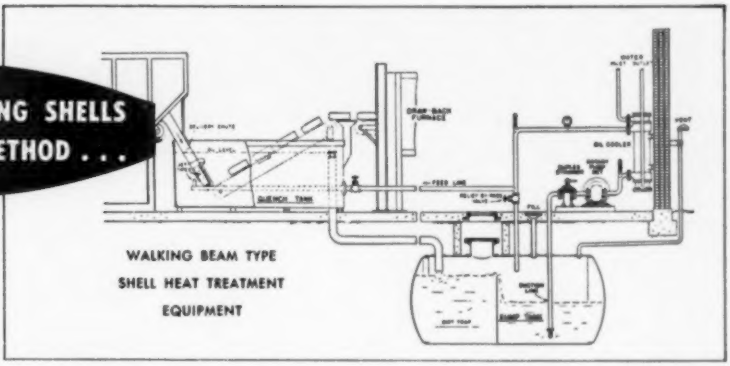
NATIONAL METAL EXPOSITION

WORLD METALLURGICAL CONGRESS

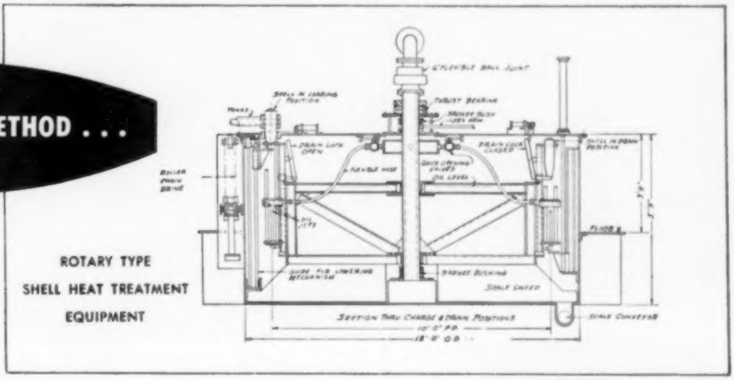
Oct. 15-19 • Detroit, Michigan

WHEN HEAT TREATING SHELLS BY THIS METHOD . . .



WALKING BEAM TYPE SHELL HEAT TREATMENT EQUIPMENT

OR BY THIS METHOD . . .



ROTARY TYPE SHELL HEAT TREATMENT EQUIPMENT

You get a faster, surer quench with proven HOUGHTO-QUENCH OIL

Selecting the proper quench is a critical step in making shells. Whatever type of steel is used — whichever quenching equipment is adopted — the right quenching oil has a lot to do with getting top results. Performance of Houghto-Quench on millions of shells in World War II proved this.

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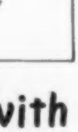
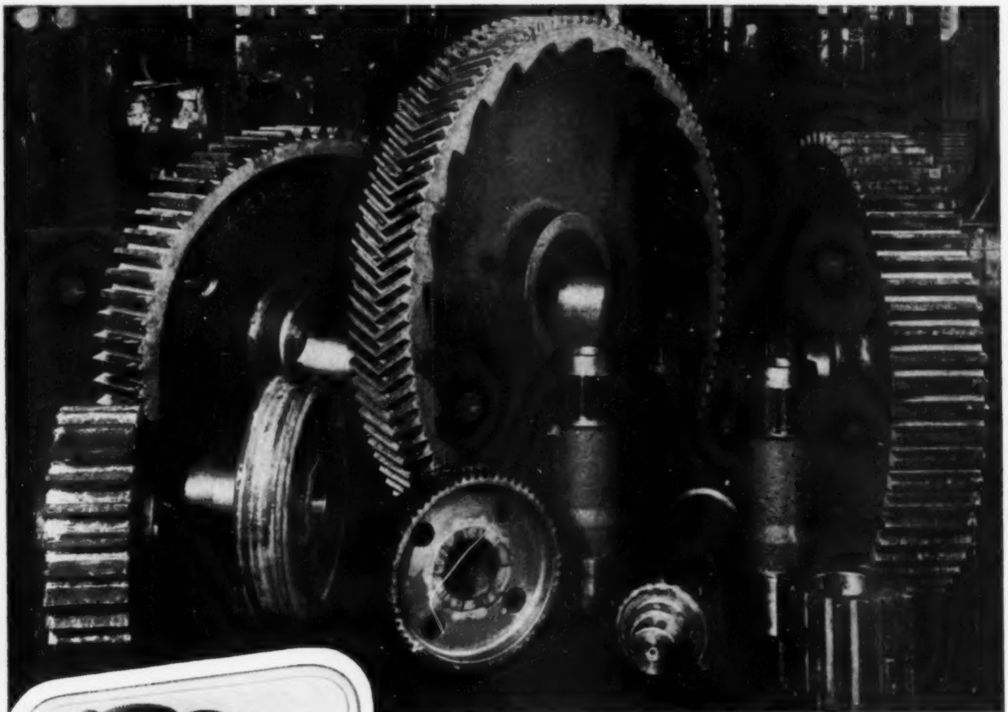
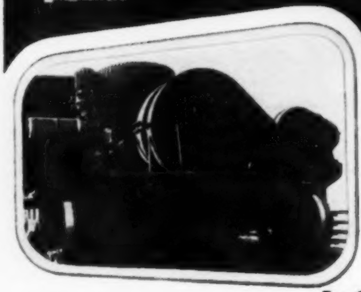


Ready to give you on-the-job service . . .





NE

CRANE GEARS and TRACK WHEELS have Greater Internal Stress Value

HERE IS WHY

For Comparative Purposes

We tabulate below the physical properties of the surface and core values of SAE-1020, SAE-2315, Steels, Carburized or Case Hardened with "Neloy" and "Neloy-Moly" Steels Normalized or Liquid Quenched, Finish Machined and Flame Hardened

S.A.E. 1020 Case-Hardened (Surface)	260/300,000	180/195,000	5–10	8–10	514–601	70–77
S.A.E. 1020 Case-Hardened (Core)	60/ 70,000	30/ 35,000	30–35	40–50	120–140	17–21
Neloy Annealed and Flame-Hardened Treatment 10B (Surface)	218/270,000	190/240,000	8–12	20–35	477–601	66–77
Neloy Annealed and Flame-Hardened Treatment 10B (Core)	85/ 90,000	55/ 65,000	23–40	30–40	163–170	25–26
S.A.E. 1020 Case-Hardened (Surface)	260/300,000	180/195,000	5–10	8–12	514–601	70–77
S.A.E. 1020 Case-Hardened (Core)	60/ 70,000	30/ 35,000	30–35	40–50	120–140	17–21
Neloy Heat Treatments No. 3 and 10B (Surface)	220/270,000	200/240,000	8–12	20–35	555–601	73–77
Neloy Heat Treatments No. 3 and 10B (Core)	100/110,000	80/ 90,000	20–26	40–50	207–241	32–36
S.A.E. 2315 Case-Hardened (Surface)	290/329,000	185/205,000	4– 8	6–10	578–653	75–81
S.A.E. 2315 Case-Hardened (Core)	112/129,000	99/120,000	12–20	38–51	248–277	37–41
Neloy-Molybdenum, Normalized, Drawn and Flame-Hardened (Surface)	258/281,000	212/247,000	6–10	8–12	514–555	70–73
Neloy-Molybdenum, Normalized, Drawn and Flame-Hardened (Core)	90/110,000*	65/ 85,000*	18–25	30–40	187–223	28–33
S.A.E. 2315 Case Hardened (Surface)	290/329,000	186/205,000	4– 8	6–10	578–653	75–81
S.A.E. 2315 Case-Hardened (Core)	112/129,000	99/120,000	12–20	38–51	248–277	37–41
Neloy-Molybdenum Heat Treatments 3A and 10B Flame-Hardened (Surface)	282/318,000	217/265,000	4– 8	6–10	555–627	73–79
Neloy-Molybdenum Heat Treatments 3A and 10B Flame-Hardened (Core)	132/150,000	120/135,000	10–18	25–35	285–321	42–47

*The variation in tensile and yield in the third table is due to the alloyed elements of 2315 which is a nickel steel. This produces a higher physical on a straight annealed steel compared with more economical alloy used in Neloy-Moly.

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25 Cr—20 Ni . . . . A.I.S.I. Type 310

MISCO 430
17 Cr . . . . A.I.S.I. Type 430

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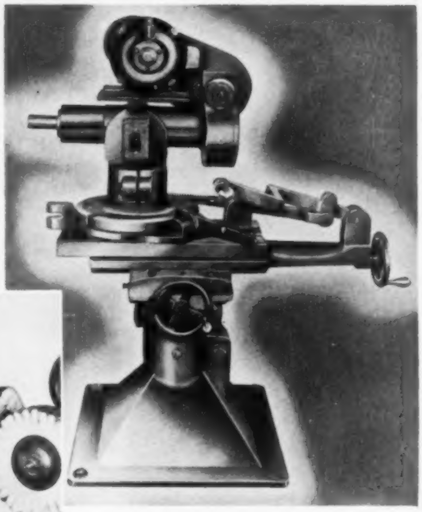
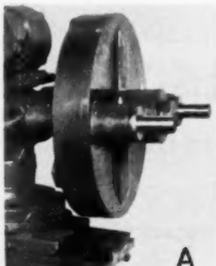
The ACME Type B-10 Semi-Automatic . . .

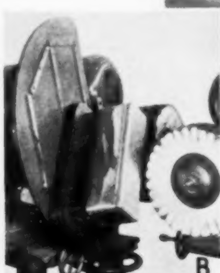
IS A VERSATILE PRODUCTION MACHINE

This machine gives very efficient production as one operator normally operates two or more units, one at each end of the lathe, loading and unloading one machine while the other has work in contact with the wheel.

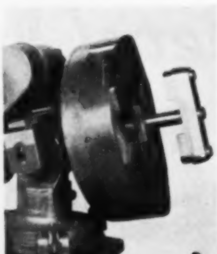




A



B



C

A Type B-10 Equipped with A-2 head handling parts up to 12" diameter. Vacuum chucking available.

B Equipped with Acme patented Geared Chuck which keeps rectangular or other out-of-round work in constant uniform contact with wheel.

Two buffs finishing sides and top in one operation.

C Geared chuck for polishing or buffing faucet bodies. Production up to 240 pieces per hour, one man handling two machines.

This single spindle machine is used with the conventional lathe for finishing such cylindrical parts as cooking utensils, plumbing goods, electrical fixtures and appliances, reflectors, hub caps, automotive accessories, and numerous other parts.

Toggle slide, vertical and cross slide adjustments permit quick set ups when changing from one job to another. Additional accessory equipment can be furnished for finishing an unusual variety of out-of-round parts as well as cylindrical work.

CATALOGS ON REQUEST

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Q-ALLOYS — THE QUALITY NAMES IN ALLOY FOR HEAT CORROSION ABRASION — **X-ite**

SO DRY!

California, in July, was so dry that the trees were chasing the dogs! Everything not well watered was as brown as the beach babes.

Things are beginning to boom as the defense industry pipeline from the Treasury, relieved from its political hot-air-lock, gets rolling.

How may relief parasites, half-baked in the sun, and otherwise, can be put to productive work,is a question. Another California "gold" (F.O.B. Taxpayer) rush may be in the making.

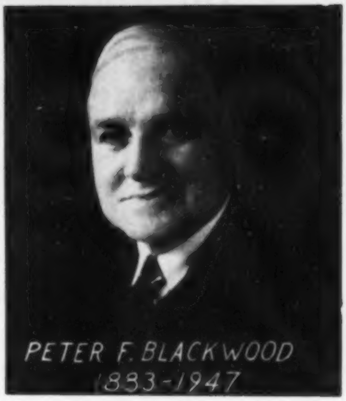
Surprising logic and foresight has planned new defense industries in Phoenix and Tuscon. With more work in such luscious-loafing spots, payrolls will bring people young enough to have children and start filling up our "great open spaces".

Swimming and diving dogs are being used to locate fire plugs in underwater areas of Kansas City. ("Sport" looks like he is afraid they will blame it on him.). "Anyway, in California and Missouri, there are tough moments in a dog's life", observed Bambi, our four-pound Rhea Pinscher who rides airlines in a camera case.

We are still whittling away at our ignorance, through scientific and demonstrably functional approaches, on casting research and development. The art of casting, with roots going deep into past centuries, still draws much of its thinking from the past. Some time, in any good museum, take a look at the castings of the Orient, of Greece and Rome, through the Italian Renaissance to the Napoleonic era in France, ranging from jewelry to heroic statuary, and you can sketch the path of a great tradition of craftsmanship now, lacking skilled molders or true craftsmen to propogate it, "foundry" must rely for needed casting improvement on tooling; *tooling that is as different from conventional molding machines and foundry equipment as machine tools differ from harvesting machinery*. New horizons in casting potentials present challenge and opportunity to American Industry.

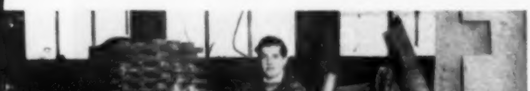
Many, many times as we carry on our expanding work on casting research and development, we think and talk of the late Peter Blackwood, Foundry Superintendent of Ford Motor of Canada and winner of the highest award of the American Foundrymen's Association. His contributions to the arts of casting metals are still timely and of great value. More important, the inspiration of the man himself, that which he contributed to the understanding of others, has inspired and projected broader work, through the geometrical progress of science.

Blackwood did not "come up the hard way" as many are alleged to have done. Peter Blackwood came up the harder and far smarter way.



He graduated as a Metallurgist, got his molders' ticket as a Journeyman, and studied cost accounting. Then he spent a sabbatical year touring the world and studying foundry practice. He left Scotland for a job in America, for he recognized, as a Scotchman, that the dollars were to be made here. He became the largest producer of steel castings used by the British, shipping them back from Canada. Pete used to say, "The better planning you do, the less bugs you have to pick out. If you have the patience and perserverance to pick them out in the beginning, they don't keep biting; those that are no longer there can't bite you".

There is no greater sport than plotting progress and crossing technical horizons. When you have picked out the current bugs and raise your sights to the next job ahead, the satisfaction more than repays the effort.



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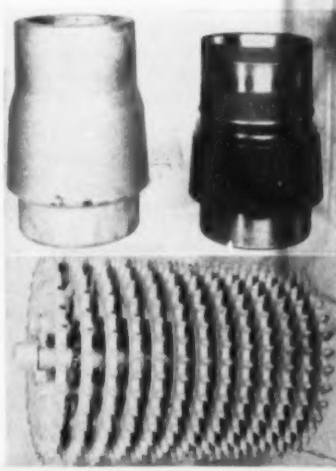

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6th METALLOGRAPHIC EXHIBIT

Rules are simple and few; there are no restrictions as to size or methods of mounting, except for entries from overseas. As in the five previous exhibits the enties will be displayed to good advantage.

RULES FOR ENTRANTS

Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable. Photographic prints shall be mounted on stiff cardboard, each on a separate mount, each carrying a label giving:

Name of metallographer
Classification of entry
Material, etchant, magnification
Any special information as desired

Transparencies or other items to be viewed by transmitted light must be mounted on light-tight boxes wired for plugging into lighting circuit, and built so they can be fixed to the wall.

Exhibits must be delivered between Sept. 20 and Oct. 10, 1951, either by prepaid express, registered parcel post, or first-class letter mail.

Address: Metallographic Exhibit
National Metal Congress and Exposition
State Fair Grounds
Woodward & State Fair Ave., Detroit, Mich.

AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which, in the opinion of the judges, closely approach the winner in excellence.

A Grand Prize, in the form of an engrossed certificate, and a money award of $100 will be awarded the exhibitor whose work is adjudged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's headquarters.

All other exhibits will be returned to owners by prepaid express or registered parcel post during the week of Oct. 22, 1951.

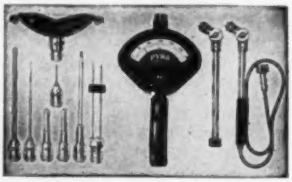
Entrants living outside the U.S.A. will do well to send their micrographs by first-class letter mail endorsed "May be opened for customs inspection before delivery to addressee". To meet regulations of the international mails, size of mount must be no larger than 14 x 18 in.

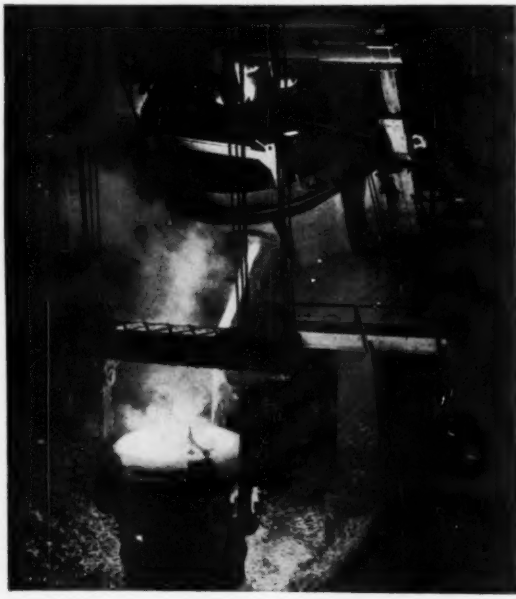
CLASSIFICATION OF MICROS

- Cast irons and cast steels
- Toolsteels (except carbides)
- Irons and alloy steels (excluding stainless) in wrought condition
- Stainless and heat resisting steels and alloys
- Light metals and alloys
- Heavy nonferrous metals and alloys
- Powder metals (and carbides) and compacts
- Weld structures (including brazed and similar joints)
- Series of micros showing transitions or changes during processing
- Surface phenomena
- Macrographs of metallurgical objects (2 to 10 diam.)
- Results by non-optical or unconventional techniques

WORLD METALLURGICAL CONGRESS
33rd NATIONAL METAL CONGRESS AND EXPOSITION

DETROIT, MICH. ***OCTOBER 15 TO 19, 1951***



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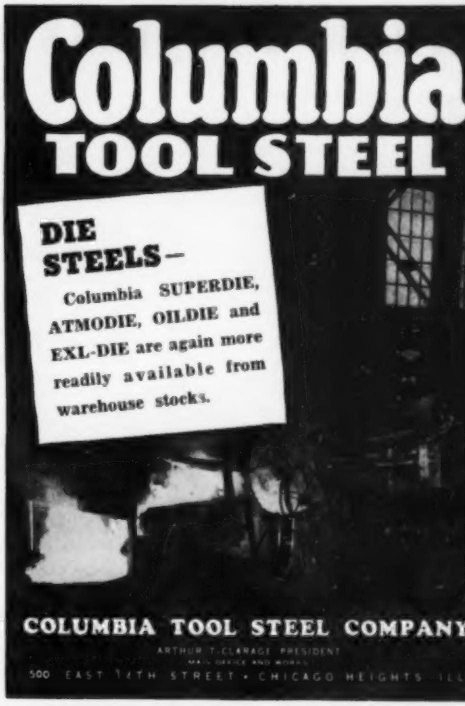
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